

XVIII. *On the Changes which take place in the Deviations of the Standard Compass in the Iron Armour-plated, Iron, and Composite-built Ships of the Royal Navy, on a considerable change of Magnetic Latitude.*

*By Staff Commander E. W. CREAK, R.N., of the Admiralty Compass Department.*

*Communicated by Sir FREDERICK J. O. EVANS, K.C.B., Hydrographer of the Admiralty.*

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THE period comprised between the years 1855–68 was one of active research into the magnetic character of the armour-plated and other ships of the Royal Navy and the iron ships of the Mercantile Navy.

It will be remembered that the Transactions of the Royal Society are rich in contributions to this important and interesting subject; important in a practical sense to the navigator, and of great interest as a subject of intelligent inquiry.

Among these contributions was a paper read before the Royal Society in March, 1865, “On the Magnetic Character of the Armour-plated ships of the Royal Navy, and on the effect on the compass of particular arrangements of Iron in a ship,” by FREDERICK JOHN EVANS, Esq., Staff Commander, R.N., F.R.S., and ARCHIBALD SMITH, Esq., M.A., F.R.S. This paper contained the earliest published results of the system of observation and analysis of the deviations of the compass in the ships of the Royal Navy, which, established in 1861, has been carried out to the present day.

These results showed the magnetic character of the several ships named, from the time of launching until fully equipped and at sea, and also an analysis of the semi-circular deviation of those ships which had made short voyages abroad. But the change of magnetic latitude through which the ships passed was so small, and the alternative of heeling the ships in one latitude so difficult, that the authors of the paper were unable to ascertain any but approximate values of the proportions of hard and soft iron affecting their compasses.

The authors write: “The determination of the proportion of the semicircular deviation, or rather of B, which arises from vertical induction in soft iron, and that which arises from the permanent or sub-permanent magnetism of hard iron, is a matter of great interest. Theoretically it may be determined in two modes, either by observing the deviation in two different magnetic latitudes, or by observing the

deviation with the ship upright and heeled over. Unfortunately there is a great want of observations under these circumstances."

During the last fifteen years long voyages into high southern magnetic inclination or dip, have been made in every class of ship in the Royal Navy, except Turret-ships, and according to the established system of the Admiralty Compass Department, the observed deviations of their compasses made in all latitudes have been analysed to obtain the values of their coefficients as shown in Table III. of this paper. From these coefficients, the constants of the hard and soft iron producing semicircular deviation at the Standard Compass positions have been computed.

A knowledge of these Constants not only provides a means of predicting for the particular ship examined the probable changes which will take place in her deviation in all parts of the navigable world, but also the power of doing the same for other ships of the same class.

Such being the case, it is thought that the Royal Society will be interested in receiving a paper treating of these subjects, commencing from the time the ships are fully equipped and ready for sea. The earlier magnetic history of the ships might have been included, but the changes which take place in their fitting, and the numerous iron bodies introduced after launching, render a comparison of the deviations observed at different stages of equipment unsatisfactory.

It is proposed to consider six classes of ships, each of which has been selected for the long range of magnetic latitude over which the ships have sailed :—

1. Iron, armour-plated.
2. Iron cased with wood.
3. Iron troop-ships.
4. Steel\* and iron cased with wood.
5. Composite built.
6. Wooden ships with iron beams and vertical bulkheads.

These ships have nearly all been launched upwards of a year previous to the observations about to be discussed, and subjected to the vibration caused by steaming at high rates of speed with powerful engines. They may therefore be considered to have attained a state of magnetic stability.<sup>†</sup>

At the close of this paper will be found in Table III. a short description of the ships, the direction in which they were built, and the coefficients for each Standard Compass.

It is not intended to repeat the several mathematical formulæ by means of which

\* The vessels have iron frames, and are plated with mild steel, containing .2 per cent. of carbon.

† See Phil. Trans., 1865, Part I., pp. 279-280.

these coefficients have been computed, as they, together with the methods of making the original observations, were so fully described in the paper on "The Magnetic Character of the Armour-plated ships of the Royal Navy," &c., 1865, to which allusion has already been made.

On comparing the results, however, in that paper with those now brought forward for discussion, a remarkable difference will be observed. In the paper for 1865, the coefficients of the semicircular deviation are those of compasses to which no mechanical correction by permanent magnets had been applied. The corresponding coefficients in the accompanying Table III. have, with the exception of the original values in England, been computed from the deviation of compasses for which a permanent bar magnet, or magnets, has been employed to annul or correct the semicircular deviation.

This correcting magnet has in every case been permanently fixed horizontally in the compass pillar, in the resultant of the magnetic forces producing semicircular deviation, and at a distance found tentatively below the card, after the several horizontal and vertical forces affecting the compass had been ascertained.

It may be asked, whether this application of correcting bar magnets of possible variable magnetic moment does not in itself introduce an element of change in the deviation in addition to those of the ship? It may be answered, with the reasonable confidence induced by fifteen years' trial, that the permanency of the magnetic moment of the magnets employed is considered to be assured.

Thus, in the ships named in the tables, the correction by magnets may be considered as the introduction into them of a permanent magnetic force acting independently on their compasses, and in opposition to the permanent magnetic forces of the ships.

It is now proposed to pass on to the chief object of this paper, which is to show the amount and direction of the changes which take place in the deviations of the standard compasses in six different classes of modern vessels in the Royal Navy, on change of magnetic latitude.

Taking the exact coefficients in Table III. in the order in which they stand we have first :—

*The constant deviation.*

**A.**

Some rather large values of this coefficient are found in the tables, but it has been proved that for standard compasses placed in the central fore and aft line of the vessel where the iron is symmetrically placed with respect to that position, little or no real value from magnetic causes has been observed. An error in the bearing of the distant object used for swinging the ship, swinging her too fast, or prism error in the azimuth circle, gives fictitious values of this coefficient, which those in the table are considered to be.

*Semicircular deviation.*

Coefficient  $\mathfrak{B} = \frac{1}{\lambda} \left( c \tan \theta + \frac{P}{H} \right)$  (approximate value in degrees = B) is the maximum of semicircular deviation from fore and aft forces;

$\frac{c}{\lambda} \tan \theta$  arises from soft iron;

$\frac{P}{\lambda H}$  from hard iron.

Coefficient  $\mathfrak{C} = \frac{1}{\lambda} \left( f \tan \theta + \frac{Q}{H} \right)$  (approximate value in degrees = C) is the maximum of semicircular deviation from transverse forces;

$\frac{f}{\lambda} \tan \theta$  arises from soft iron, and is zero if the iron is symmetrically arranged;

$\frac{Q}{\lambda H}$  from hard iron.

For determining P and c separately, when  $\mathfrak{B}$  has been determined in two different magnetic latitudes, the foregoing equations are put under the form,

$$\frac{P}{\lambda} + \frac{c}{\lambda} H \tan \theta = \mathfrak{B} H$$

$$\frac{P}{\lambda} + \frac{c}{\lambda} H' \tan \theta' = \mathfrak{B}' H'$$

and similarly for Q and f when  $\mathfrak{C}$  has been determined in two different latitudes.

From the values of  $\mathfrak{B}$  and  $\mathfrak{C}$  in the table, the constants P and c, Q and f, have been calculated by the above formulæ, and the results are given in Table I., which for convenience has been placed at the end of this paper.

The explanation of this table is as follows :—

The quantities found in the columns headed "Original P" and "Original Q" are the constants P and Q, arising from the hard iron of the ship before correction by magnets, and which are mainly dependent for their values and sign upon the direction in which the ship's head lay during building. This direction is given under each ship's name.

In the columns headed "Corrected P" and "Corrected Q" are shown the constants P and Q as altered by the correcting magnets.

The quantities  $\frac{c}{\lambda} \tan \theta$  and  $\frac{f}{\lambda} \tan \theta$  (with their equivalents expressed in degrees) are the changing parts of the coefficients  $\mathfrak{B}$  and  $\mathfrak{C}$  respectively, for the South of England, which can only be corrected for all latitudes by vertical soft iron bars.

From the constants c and f in the remaining columns, the changing part of the

coefficients  $\mathfrak{B}$  and  $\mathfrak{C}$ , arising from vertical induction in soft iron, may be computed whenever the magnetic inclination or dip is known, or can be taken from charts of that element.

Before further investigating the effects of a change of magnetic latitude on the coefficients, the question of how far time affects the constants  $P$  and  $Q$  requires consideration.

On looking over the values of  $P$  and  $Q$ , it will be remarked that in some ships a change takes place immediately after leaving England, which appears to be neither due to time nor change of latitude, but to another cause which will hereafter be referred to. Taking the values obtained subsequently at different times in the same geographical position it will be found—

|                                      |                           | P.                      | Change.          | Q.              | Change.         |
|--------------------------------------|---------------------------|-------------------------|------------------|-----------------|-----------------|
| Bellerophon.—Quebec . . . . .        | { 1874<br>1876            | −·002<br>−·020          | } ·018           | −·003<br>−·008  | } ·005          |
| Iron Duke.—Hong-Kong . . . . .       | { 1880<br>1881            | −·208<br>−·193          | } ·015           | −·002<br>−·037  | } ·035          |
| Northampton.—Halifax, N.S. . . . .   | { vi. 1880<br>x. 1880     | +·024<br>+·032          | } ·008           | −·037<br>−·057  | } ·020          |
| Active.—Simon's Bay, C. G. Hope . .  | { x. 1874<br>x. 1876      | −·120<br>−·096          | } ·024           | −·019<br>−·006  | } ·013          |
| Raleigh.—Spithead . . . . .          | { ix. 1874<br>vi. 1876    | +·043<br>+·057          | } ·014           | +·026<br>+·001  | } ·025          |
| Inconstant.—Spithead . . . . .       | { viii. 1869<br>xi. 1871  | −·023<br>−·044          | } ·021           | +·016<br>+·017  | } ·001          |
| Himalaya.—{ Plymouth . . . . .       | { vii. 1872<br>vii. 1874  | −·030<br>−·021          | } ·009           | −·061<br>−·058  | } ·003          |
|                                      | { Simon's Bay, C. G. Hope | { viii. 1872<br>i. 1875 | { −·030<br>−·021 | { ·009<br>−·081 | { ·039<br>−·039 |
| Albatross.—Sheerness and Plymouth .  | { iii. 1874<br>x. 1874    | −·066<br>−·064          | } ·002           | +·015<br>+·022  | } ·007          |
| Boxer.—Esquimault, V. I. . . . .     | { x. 1869<br>x. 1874      | −·008<br>−·004          | } ·004           | −·049<br>−·030  | } ·019          |
| Encounter.—Simon's Bay, C. G. Hope . | { iv. 1874<br>i. 1876     | +·002<br>−·048          | } ·050           | +·022<br>−·001  | } ·023          |

Thus, in the worst case amongst the armour-plated, iron, and composite vessels,  $P$  takes a year to alter ·015, and generally two or three years for about half that amount. A change of ·015 in  $P$  would make about a degree change in the deviation. This evidently slow change of  $P$  by time is important, as should  $P$  alter during the ship's sailing over a long range of magnetic latitude, the values of  $c$ , as found by the above formulæ, are correspondingly untrustworthy.

With regard to the constant  $Q$ , although more subject to change by time than  $P$ , it is comparatively of less importance, as, with few exceptions, the value of the constant  $f$ , which depends on the constancy of  $Q$ , is, if not zero, so small as to be neglected.

Having accepted as the result of fifteen years' trial that the correcting bar magnets

are of constant magnetic moment, it would be reasonable to expect that the constants P and Q should remain unchanged in value, except the small decrease due to time. This is nearly the case, yet there are small fluctuations in them which demand notice.

It is known that if an iron vessel be placed in dock for any length of time in one direction with respect to the magnetic meridian, the values of P, and especially Q, undergo small changes dependent upon that relation. If, in addition, the vessel be subjected at the same time to concussion, from whatever cause, the change is greater. On the return of the vessel to her anchorage, or on proceeding to sea when the direction of her head varies frequently, P and Q return slowly to their original value.

It may therefore be inferred, that although P and Q as shown in the tables are for the most part due to permanent magnetism in the hard iron of the ship, there is a small part which is sub-permanent and subject to alterations from concussion, or the vibratory motion caused in the ship by powerful steam-engines when proceeding in a given direction for several days. On the removal of the cause inducing the change in P and Q they gradually return to their original values.

In the turret ships of the Royal Navy, where the standard compass is necessarily placed on a thin iron superstructure, this temporary dislocation of parts of P and Q, caused by the concussion of firing heavy guns and subsequent gradual recovery, is well known and provided for on board by constant observation for deviation of the compass.

Before considering the constants  $c$  and  $f$ , which represent the chief part of the changes which take place in the deviation of the compass on change of magnetic latitude, a few preliminary remarks appear to be necessary.

In "Contributions to Terrestrial Magnetism," No. IX.,\* Sir EDWARD SABINE records the result of his investigations as to the effects of a change of magnetic latitude on the deviation of the Standard Compass of some wooden sailing ships of forty years ago. He concluded that their deviations were caused by vertical induction in soft iron, that they did not change directly in proportion to the dip, but there was a lagging behind proceeding from a slowness in the soft iron to part with its induced magnetism. For example, a ship passing quickly from  $40^{\circ}$  N. to  $20^{\circ}$  N., dip, would find the deviation due to vertical induction in  $20^{\circ}$  N., dip, to be that of  $30^{\circ}$  or  $32^{\circ}$  N.

In considering how far this theory applies to modern armour-plated and iron vessels, it may help to clear the question to note the rapidity with which horizontal soft iron, when magnetised by the earth's horizontal force, takes up and parts with its induced magnetism, as exemplified in swinging a ship for deviation of the compass.

In this operation—during which the direction of the ship's head passes through a complete circle—the deviation caused by horizontal induction in soft iron attains two maxima in an easterly and two in a westerly direction within an hour and a half.

\* See Phil. Trans., 1849.

Looking to this result, it hardly seems probable that vertical induction in soft iron should be slower in its action, and require perhaps days for full development.

Among the iron armour-plated ships of the tables we have, in the case of the "Triumph" and "Swiftsure" (two sister ships), experimental evidence that there is no sign of "lagging" in the changing part of their deviation, but that it alters directly as the tangent of the dip for any given position of the ship.

Both vessels, from requirements of the service, have their standard compasses placed unusually far from the stern, in a position 13 feet from the top of an armour-plated transverse bulkhead 5 inches thick. These ships were swung in the course of a few successive months, the observed deviations in each case but one corresponding with the dip at the locality, the values of which were as follows:—

|                     | $\theta.$   |                              |
|---------------------|---|------------------------------|
| Triumph . . . . .   | $\left\{ \begin{array}{l} -44^\circ \\ -34 \\ -3 \\ +38 \end{array} \right\}$         | Range of $\theta 82^\circ.$  |
| Swiftsure . . . . . | $\left\{ \begin{array}{l} +67^\circ \\ +17 \\ -11 \\ -29 \\ -52 \end{array} \right\}$ | Range of $\theta 119^\circ.$ |

To proceed with the constants  $c$  and  $f$ .

The values of  $c$  are very valuable, not only as a means of predicting the probable change of deviation for the particular ships in which they are known, but also for ships of similar construction. As an illustration of the similarity of this constant in certain ships, the following examples are given where sister ships are bracketed:—

|                         | $c.$  |
|-------------------------|-------|
| { Triumph . . . . .     | +·106 |
| { Swiftsure . . . . .   | +·110 |
| { Northampton . . . . . | -·021 |
| { Nelson . . . . .      | -·014 |
| Shah . . . . .          | -·005 |
| Raleigh . . . . .       | -·006 |
| { Comus . . . . .       | +·034 |
| { Cleopatra . . . . .   | +·032 |
| Carysfort* . . . . .    | +·044 |
| { Boxer . . . . .       | +·023 |
| { Pert . . . . .        | +·026 |
| Firefly . . . . .       | +·005 |
| Wrangler . . . . .      | +·002 |

\* The "Carysfort" is a sister ship to "Comus" in every respect, with the exception that the former has no vertical iron shaft through which the screw is raised. In the "Comus" and "Cleopatra" this shaft is 30 feet from the compass.

From the position of the standard compass in the "Northampton" and "Nelson," 83 feet from the stern, a positive value of  $c$  might have been expected; but there is a transverse armoured bulkhead, 8 inches thick, the top of which is 30 feet nearer the stern than the compass in each vessel, which is the probable cause of the minus sign for  $c$ .

It is a subject for further inquiry as to what extent iron masts contribute to the values of  $c$  when the Standard Compass is placed near them. A series of experiments was made near Athens, where the magnetic dip is approximately  $53^\circ$  N., and at Singapore, in  $13^\circ$  S. dip, on board the "Ruby."\* The Standard Compass of this ship is placed at 6 feet 9 inches from the iron mizenmast. The results showed that at three different parts of the mast (on a level with the compass, and a few feet above, and below that level) the effects of transient induction were very small, and that the mast acted almost entirely as a permanent magnet.

The remaining constant of the semicircular deviation,  $f$ , is one which has hitherto been accepted as zero, from the iron in the transverse section of the ships of the Royal Navy—except turret ships—being considered as placed symmetrically with respect to the Standard Compass.

In the Table I., however, there are five ships for which values of  $f$  have been discovered, and one, the "Triumph," in which it reaches an amount which could not be disregarded in a forecast of that vessel's deviation for any given geographical position. From Table I. the following values of  $f$  have been collected:—

|                       | $f$ . | $\frac{f}{\lambda} \tan \theta$ in England. |
|-----------------------|-------|---|
| Bellerophon . . . . . | −·005 | −·012 = $0^\circ 42'$                       |
| Triumph . . . . .     | −·013 | −·038 = $2^\circ 10'$                       |
| Swiftsure . . . . .   | +·004 | +·010 = $0^\circ 35'$                       |
| Active . . . . .      | +·004 | +·010 = $0^\circ 35'$                       |
| Himalaya . . . . .    | +·006 | +·015 = $0^\circ 52'$                       |
| Comus . . . . .       | −·004 | −·010 = $0^\circ 35'$                       |

From the peculiar construction of some of the later types of armour-plated ships the constant  $f$  will probably attain higher values than those hitherto experienced.

#### *Quadrantal deviation.*

Coefficient  $\mathfrak{D} = \frac{a-e}{2\lambda}$  (approximate value in degrees = D) is the maximum of quadrantal deviation from soft iron symmetrically placed.

Coefficient  $\mathfrak{E} = \frac{d+b}{2\lambda}$  (approximate value in degrees = E) is the maximum of quadrantal deviation from soft iron unsymmetrically placed.

\* These experiments were made by Navigating Lieutenant HENDERSON, R.N., of the "Ruby."

On again referring to the paper "On the Magnetic Character of the Armour-plated Ships, &c.," of 1865, we read at page 275, "D and E do not change with a change of geographical position."

As regards  $\mathfrak{D}$  this is fully confirmed by the results in the tables. Time alone appears to cause a gradual change in this coefficient during the first two or three years after launching, after which it remains remarkably permanent.

Coefficient  $\mathfrak{C}$  has no real value in the ships under discussion.

#### *Coefficient $\lambda$ .*

$\lambda = 1 + \frac{a+e}{2}$  is a factor generally less than 1, giving the northern component of the mean directive force of the needle, or "mean force to north."

$\lambda$ , as might be expected from its close connexion with  $\mathfrak{D}$ , appears to be affected solely by lapse of time similarly to  $\mathfrak{D}$ ; for example, in the "Malabar" (a sister ship to the "Euphrates" of the tables), a valuable series of observations was made between England and Bombay,\* the results of which are here recorded.

|  | $\lambda$ . |
|--|-------------|
| Malabar.—Spithead, 17 vi. 67 . . . . .             | ·861        |
| Aden, 10 i. 70 . . . . .                           | ·861        |
| Bombay, $\frac{1}{2} \frac{1}{3}$ ii. 70 . . . . . | ·906        |
| Suez, xi. 70 . . . . .                             | ·907        |
| Spithead, 5 ix. 71 . . . . .                       | ·932        |
| Spithead, 28 x. 78 . . . . .                       | ·930        |

Each of the above values of  $\lambda$  is the mean of several observations conducted under favourable circumstances, and the observations, as far as they go, confirm the conclusions drawn from other ships in England. The ship's visit to the heat of the tropics seems to have accelerated the change in  $\lambda$ .

#### *Coefficient $\mu$ .*

$\mu = 1 + k + \frac{R}{Z}$ , in which  $k$  represents the vertical force caused by vertical induction in the soft iron of the ship;  $R$  the vertical force from the hard iron.

The values of  $\mu$  contribute largely in many ships to the heeling error. For the purpose of eliminating the values of  $k$  from  $R$  observations in widely different magnetic latitudes are still required.

\* By Staff Commander J. C. RICHARDS, R.N.

In order to show the relative proportions of hard to soft iron affecting the standard compasses of the ships named in the tables—which are cruisers liable to be sent on long voyages—the values of  $\sqrt{P^2+Q^2}$  and  $\sqrt{c^2+f^2}$  have been placed together here—

|                                       | $\sqrt{P^2+Q^2}$ | $\sqrt{c^2+f^2}$ |
|---------------------------------------|------------------|------------------|
| Iron armour-plated ships—             |                  |                  |
| Bellerophon . . . . .                 | .216             | .005             |
| Iron Duke . . . . .                   | .416             | .060             |
| Triumph . . . . .                     | .039             | .106             |
| Swiftsure . . . . .                   | .058             | .110             |
| Northampton . . . . .                 | .345             | .021             |
| Nelson . . . . .                      | .287             | .024             |
| Iron vessels cased with wood—         |                  |                  |
| Active . . . . .                      | .541             | .016             |
| Shah . . . . .                        | .173             | .005             |
| Raleigh . . . . .                     | .282             | .006             |
| Inconstant . . . . .                  | .238             | .039             |
| Iron troop-ships—                     |                  |                  |
| Euphrates . . . . .                   | .359             | .027             |
| Himalaya . . . . .                    | .281             | .009             |
| Orontes . . . . .                     | .219             | .029             |
| Steel and iron ships cased with wood— |                  |                  |
| Comus . . . . .                       | .238             | .034             |
| Carysfort . . . . .                   | .263             | .044             |
| Cleopatra . . . . .                   | .076             | .032             |
| Composite vessels—                    |                  |                  |
| Ruby . . . . .                        | .500             | .027             |
| Gannet . . . . .                      | .185             | .024             |
| Albatross . . . . .                   | .232             | .029             |
| Boxer. . . . .                        | .196             | .023             |
| Pert . . . . .                        | .244             | .026             |
| Firefly . . . . .                     | .332             | .005             |
| Wrangler . . . . .                    | .375             | .002             |
| Wooden ships with iron beams, &c.—    |                  |                  |
| Encounter . . . . .                   | .234             | .018             |
| Sapphire . . . . .                    | .233             | .045             |

On looking through the above values of  $\sqrt{P^2+Q^2}$ , it will be noticed that large differences occur in ships of similar construction.

It will be remembered that all iron and composite vessels are large magnets,

generally of widely different forms. The values of  $\sqrt{P^2+Q^2}$  are, therefore, chiefly dependent upon the position which the standard compass occupies on board these ships, considered as magnets.

Again, each iron body introduced during equipment into that great magnet, the ship, tends to modify in one direction or another its action upon the compass.

Consequently, if the compass be moved from the stern along the central longitudinal line of a ship towards her bow, it will be subjected to the influence of forces varying from those of repulsion or attraction, to zero, and then to those of attraction or repulsion.

For example, the "Iron Duke" and the "Triumph"—although not sister ships—are alike in many points, and built nearly in the same direction.

|                 | $\sqrt{P^2+Q^2}$ . | Distance of standard compass from stern. |
|-----------------|--------------------|--|
| Iron Duke . . . | .416               | 81 feet.                                 |
| Triumph . . .   | .033               | 105 ,,                                   |

It might at first sight be inferred from these results, that the position of the compass in "Triumph" is better than in the "Iron Duke." Keeping in view the object—always much desired—of so placing the compass as to have, when corrected, small changes of deviation on change of magnetic latitude, it will be seen this is not the case.

A reference to the values of  $\sqrt{c^2+f^2}$ , representing the changing part of the deviation, shows that in the "Iron Duke" the value is +.060; in the "Triumph" it is +.106. Thus, the "Triumph's" compass would be improved as regards deviation by moving it further towards the stern and away from the armour-plated bulkhead causing the large value of  $c$ , and opposing the increased value of  $P$  which would ensue, by a bar magnet.

These considerations tend to show the importance of the long-established regulations with regard to the placing of the standard compass in ships of the Royal Navy, which provide, that the best possible position with regard to surrounding iron shall be selected for it, subject to the interests of the ship as an engine of war.

#### *General Conclusions.*

The following general conclusions have especial reference to the Standard Compass positions in those vessels mentioned in the tables, and to all others of similar types.

1. A large proportion of the semicircular deviation is due to permanent magnetism in hard iron.

2. A large proportion of the semicircular deviation may be reduced to zero, or corrected for all magnetic latitudes, by fixing a hard steel bar magnet or magnets in the compass pillar in opposition to and of equal force to the forces producing that deviation.

3. A very small proportion of the semicircular deviation is due to sub-permanent magnetism, which diminishes slowly by lapse of time.

4. The sub-permanent magnetism produces deviation in the same direction as the permanent magnetism in hard iron, except when temporarily disturbed, (1) by the ship's remaining in a constant position with respect to the magnetic meridian for several days, (2) by concussion, (3) or by both combined, when the disturbance is intensified.

5. To ascertain the full value of changes in the sub-permanent magnetism, observations should be taken immediately on removal of the inducing cause.

6. In the usual place of the standard compass the deviation caused by transient vertical induction in soft iron is small, and of the same value (nearly) for ships of similar construction.

7. The preceding conclusions point to the conditions which should govern the selection of a suitable position for the standard compass with regard to surrounding iron in the ship.

TABLE I.—Values of the Constant Parameters P and  $c$ , Q and  $f$ , at Standard Compass Positions in Her Majesty's Ships.

| Geographical position.   | Date of observation. | Original P. | Corrected P. | $\frac{c}{\lambda} \tan \theta$<br>in England. | $c$ . | Original Q. | Corrected Q. | $\frac{f}{\lambda} \tan \theta$<br>in England. | $f$ .          |
|--|----------------------|-------------|--------------|--|-------|-------------|--------------|--|----------------|
| <i>Armour-plated ships.</i>  |                      |             |              |  |       |             |              |  |                |
| BELLEROPHON.—Built S. $51^\circ$ E. Distance of standard from stern 61 feet, from iron mast 15 feet.             |                      |             |              |  |       |             |              |  |                |
| Spithead . . .   | 3 xi. 73             | +·024       | -·004        | 0  | 0     | +·215       | +·025        | -·012  | -·005          |
| Halifax, N.S. . .  | 5 viii. 74           | ..          | +·031        | ..   | ..    | ..          | -·002        | =  | $-0^\circ 42'$ |
| Quebec . . .   | 16 ix. 74            | ..          | -·002        | ..   | ..    | ..          | -·003        |  |                |
| Trinidad . . .   | 1 iii. 76            | ..          | -·020        | ..   | ..    | ..          | -·003        |  |                |
| Halifax, N.S. . .  | 21 vi. 76            | ..          | -·020        | ..   | ..    | ..          | -·010        |  |                |
| Quebec . . .   | 24 viii. 76          | ..          | -·020        | ..   | ..    | ..          | -·008        |  |                |
| IRON DUKE.—Built S. $39^\circ$ W. Distance of standard from stern 81 feet, from iron mast $17\frac{1}{2}$ feet.  |                      |             |              |  |       |             |              |  |                |
| Plymouth . . .   | 20 i. 71             | +·407       | ..           | +·158  | +·060 | -·166       | ..           |  |                |
| " . . .  | 16 ix. 71            | ..          | -·019        | +·9° 5'  | ..    | ..          | +·048        |  |                |
| Gibraltar . . .  | x. 71                | ..          | -·047        | ..   | ..    | ..          | -·008        |  |                |
| $6^\circ$ N. $96^\circ$ E. . .   | 10 xii. 71           | ..          | -·047        | ..   | ..    | ..          | +·097        |  |                |
| $38^\circ$ N. $136^\circ$ E. . .   | 22 viii. 72          | ..          | -·110        | ..   | ..    | ..          | +·010        |  |                |
| $49^\circ$ N. $140^\circ$ E. . .   | viii. 73             | ..          | -·099        | ..   | ..    | ..          | +·028        |  |                |
| $30^\circ$ N. $133\frac{1}{2}^\circ$ E. . .  | 27 vii. 74           | ..          | -·123        | ..   | ..    | ..          | +·054        |  |                |
| $12\frac{3}{4}^\circ$ N. $46^\circ$ E. . .   | 11 iii. 75           | ..          | -·126        | ..   | ..    | ..          | -·016        |  |                |
| Plymouth . . .   | 27 vii. 75           | ..          | -·136        | ..   | ..    | ..          | +·042        |  |                |
| Belfast . . .  | 5 ix. 76             | ..          | -·138        | ..   | ..    | ..          | +·034        |  |                |
| Plymouth . . .   | 18 vii. 78*          | +·402*      | -·122†       | ..   | ..    | -·108       | -·022†       |  |                |
| Singapore . . .  | xi. 78               | ..          | -·193        | ..   | ..    | ..          | +·031        |  |                |
| Yokohama . . .   | vii. 79              | ..          | -·193        | ..   | ..    | ..          | -·021        |  |                |
| Hong Kong . . .  | 28 xii. 80           | ..          | -·208        | ..   | ..    | ..          | -·002        |  |                |
| " . . .  | 31 xii. 81           | ..          | -·193        | ..   | ..    | ..          | -·037        |  |                |
| TRIUMPH.—Built S. $45^\circ$ W. Distance of standard from stern 105 feet, from iron mast $27\frac{1}{2}$ feet.   |                      |             |              |  |       |             |              |  |                |
| Spithead . . .   | 15 v. 78             | -·033       | -·289        | +·304  | +·106 | -·020       | +·044        | -·038  | -·013          |
| Equator, $24\frac{1}{2}^\circ$ W. . .  | 20 vi. 78            | ..          | -·222        | +·17° 40'                                      | ..    | ..          | -·012        | =  | $-2^\circ 10'$ |
| $23^\circ$ S. $39^\circ$ W. . .  | 1 vii. 78            | ..          | -·214        | ..   | ..    | ..          | +·009        |  |                |
| $40\frac{1}{2}^\circ$ S. $78\frac{3}{4}^\circ$ W. . .  | 7 vii. 78            | ..          | -·194        | ..   | ..    | ..          | -·001        |  |                |
| Valparaiso . . .   | x. 78                | ..          | -·190        | ..   | ..    | ..          | -·007        |  |                |
| $9\frac{1}{4}^\circ$ S. $80\frac{3}{4}^\circ$ W. . .   | 7 ii. 79             | ..          | -·209        | ..   | ..    | ..          | -·001        |  |                |
| $20^\circ$ N. $157^\circ$ W. . .   | 4 iv. 79             | ..          | -·195        | ..   | ..    | ..          | -·003        |  |                |
| SWIFTSURE.—Built S. $56^\circ$ W. Distance of standard from stern 107 feet, from iron mast $28\frac{3}{4}$ feet. |                      |             |              |  |       |             |              |  |                |
| Plymouth . . .   | 8 v. 82              | -·057       | -·233        | +·304  | +·110 | +·010       | -·016        | +·010  | +·004          |
| $1^\circ$ S. $26^\circ$ W. . .   | 22 vi. 82            | ..          | -·182        | +·17° 40'                                      | ..    | ..          | -·007        | =  | $0^\circ 35'$  |
| $23^\circ$ S. $43^\circ$ W. . .  | 5 vii. 82            | ..          | -·227        | ..   | ..    | ..          | -·086        |  |                |
| Monte Video . . .  | 23 vii. 82           | ..          | -·236        | ..   | ..    | ..          | -·031        |  |                |
| Sandy Point, Magellan Straits . . .  | 4 viii. 82           | ..          | -·239        | ..   | ..    | ..          | -·016        |  |                |

\* Previous to this date the ship had been under repair at Birkenhead.

† After re-correction by a permanent magnet.

TABLE I.—Values of the Constant Parameters P and  $c$ , Q and  $f$ , at Standard Compass Positions in Her Majesty's Ships (continued).

| Geographical position.  | Date of observation. | Original P. | Corrected P. | $\frac{c}{\lambda} \tan \theta$<br>in England. | $c$ . | Original Q. | Corrected Q. | $\frac{f}{\lambda} \tan \theta$<br>in England. | $f$ . |
|---|----------------------|-------------|--------------|--|-------|-------------|--------------|--|-------|
| <i>Armour-plated ships (continued).</i>   |                      |             |              |  |       |             |              |  |       |
| NORTHAMPTON.—Built S. $6^\circ$ E. Distance of standard from stern 83 feet, from iron mast 22 feet.                       |                      |             |              |  |       |             |              |  |       |
| Sheerness . . .   | 1 xi. 79             | +·345       | ..           | -·060 }<br>=                                   | -·021 | -·008       | -·002        |  |       |
| Spithead . . .  | 18 xii. 79           | ..          | +·050        | - $3^\circ 25'$ }                              | ..    | ..          | -·002        |  |       |
| $27\frac{1}{2}^\circ$ N. $62\frac{3}{4}^\circ$ W. . .   | 23 i. 80             | ..          | +·060        | ..   | ..    | ..          | -·053        |  |       |
| St. Lucia . . .   | 20 ii. 80            | ..          | +·041        | ..   | ..    | ..          | -·073        |  |       |
| Bermuda . . .   | 8 v. 80              | ..          | +·082        | ..   | ..    | ..          | -·090        |  |       |
| Halifax, N.S. . .   | 27 vi. 80            | ..          | +·024        | ..   | ..    | ..          | -·037        |  |       |
| Rimouski, River<br>St. Lawrence . . .   | 21 viii. 80          | ..          | +·046        | ..   | ..    | ..          | -·046        |  |       |
| Halifax, N.S. . .   | 1 x. 80              | ..          | +·032        | ..   | ..    | ..          | -·057        |  |       |
| Dominica . . .  | 22 i. 81             | ..          | +·046        | ..   | ..    | ..          | -·004        |  |       |
| NELSON.—Built S. $21^\circ$ E. Distance of standard from stern 83 feet, from iron mast 23 feet.                           |                      |             |              |  |       |             |              |  |       |
| Sheerness . . .   | 28 vii. 81           | +·281       | ..           | -·043 }<br>=                                   | -·014 | -·060       | ..           |  |       |
| Plymouth . . .  | 28 ix. 81            | ..          | +·032        | - $2^\circ 30'$ }                              | ..    | ..          | +·027        |  |       |
| Madeira . . .   | 11 x. 81             | ..          | +·048        | ..   | ..    | ..          | +·016        |  |       |
| Simon's Bay, C.<br>G. Hope . . .  | 14 xi. 81            | ..          | +·048        | ..   | ..    | ..          | +·040        |  |       |
| <i>Iron ships cased with wood.</i>  |                      |             |              |  |       |             |              |  |       |
| ACTIVE.—Built N. $33^\circ$ E. Distance of standard from stern 69 feet, from iron mast $16\frac{1}{2}$ feet.              |                      |             |              |  |       |             |              |  |       |
| Portsmouth . . .  | 13 x. 73             | -·541       | -·120        | +·039 }<br>=                                   | +·015 | +·024       | ..           | +·010 }<br>=                                   | +·004 |
| " . . .   | 15 x. 73             | ..          | -·120        | + $2^\circ 15'$ }                              | ..    | ..          | -·019        | + $0^\circ 35'$ }                              |       |
| Simon's Bay, C.<br>Good Hope . . .  | x. 74                | ..          | -·120        | ..   | ..    | ..          | -·019        |  |       |
| " . . .   | x. 75                | ..          | -·094        | ..   | ..    | ..          | -·023        |  |       |
| " . . .   | xi. 76               | ..          | -·096        | ..   | ..    | ..          | -·006        |  |       |
| SHAH.—Built S. $70^\circ$ E. Distance of standard from stern 70 feet, from iron mast $17\frac{1}{2}$ feet.                |                      |             |              |  |       |             |              |  |       |
| Spithead . . .  | 8 vii. 76            | +·003       | ..           | -·012 }<br>=                                   | -·005 | +·173       | ..           |  |       |
| " . . .   | 4 x. 76              | ..          | +·009        | - $0^\circ 42'$ }                              | ..    | ..          | +·083        |  |       |
| Esquimaault, Vancouver's Island. . .  | x. 77                | ..          | -·017        | ..   | ..    | ..          | -·067        |  |       |
| Coquimbo . . .  | 8 iii. 78            | ..          | -·017        | ..   | ..    | ..          | -·002        |  |       |
| Panama . . .  | 11 v. 78             | ..          | -·010        | ..   | ..    | ..          | +·002        |  |       |
| RALEIGH.—Built S. $51^\circ$ E. Distance of standard from stern $65\frac{1}{2}$ feet, from iron mast $8\frac{3}{4}$ feet. |                      |             |              |  |       |             |              |  |       |
| Sheerness . . .   | 6 vi. 74             | +·195       | ..           | -·017 }<br>=                                   | -·006 | +·203       | ..           |  |       |
| " . . .   | 8 vi. 74             | ..          | +·029        | - $1^\circ 0'$ }                               | ..    | ..          | +·054        |  |       |
| Spithead . . .  | 18 ix. 74            | ..          | +·043        | ..   | ..    | ..          | +·003        |  |       |
| Simon's Bay, C.<br>Good Hope . . .  | iii. 75              | ..          | +·043        | ..   | ..    | ..          | +·026        |  |       |
| Bombay . . .  | 29 x. 75             | ..          | -·006        | ..   | ..    | ..          | -·010        |  |       |
| Spithead . . .  | 14 vi. 76            | ..          | +·057        | ..   | ..    | ..          | +·001        |  |       |

TABLE I.—Values of the Constant Parameters P and  $c$ , Q and  $f$ , at Standard Compass Positions in Her Majesty's Ships (continued).

| Geographical position.  | Date of observation. | Original P. | Corrected P. | $\frac{c}{\lambda} \tan \theta$ in England. | $c$ . | Original Q. | Corrected Q. | $\frac{f}{\lambda} \tan \theta$ in England. | $f$ . |
|---|----------------------|-------------|--------------|---|-------|-------------|--------------|---|-------|
| <i>Iron ships cased with wood (continued).</i>  |                      |             |              |   |       |             |              |   |       |
| INCONSTANT.—Built S. $38^{\circ}$ W. Distance of standard from stern 79 feet, from iron mast 13 feet.             |                      |             |              |   |       |             |              |   |       |
| Spithead . . .  | 19 viii. 69          | +·297       | ..           | +·107 }<br>=                                | +·039 | -·124       | ..           |   |       |
| " . . .   | 20 viii. 69          | ..          | -·023        | + $6^{\circ} 10'$ }                         | ..    | ..          | +·016        |   |       |
| Plymouth . . .  | 21 viii. 70          | ..          | -·071        | ..  | ..    | ..          | +·020        |   |       |
| Spithead . . .  | 18 xi. 71            | ..          | -·044        | ..  | ..    | ..          | +·017        |   |       |
| Rio de Janeiro .  | 9 i. 72              | ..          | -·044        | ..  | ..    | ..          | -·015        |   |       |
| Spithead . . .  | 12 x. 80             | +·238       | ..           | ..  | ..    | +·010       | ..           |   |       |
| " . . .   | 14 x. 80             | ..          | -·094*       | ..  | ..    | ..          | -·005*       |   |       |
| Melbourne . . .   | vii. 81              | ..          | -·150        | ..  | ..    | ..          | +·031        |   |       |
| Simonoseki . . .  | 15 xi. 81            | ..          | -·150        | ..  | ..    | ..          | -·041        |   |       |
| Simon's Bay, C.   |                      |             |              |   |       |             |              |   |       |
| Good Hope . . .   | v. 82                | ..          | -·131        | ..  | ..    | ..          | -·020        |   |       |
| <i>Iron troopships.</i>   |                      |             |              |   |       |             |              |   |       |
| EUPHRATES.—Built N. $67^{\circ}$ W. Distance of standard from stern 96 feet, from iron mast $33\frac{3}{4}$ feet. |                      |             |              |   |       |             |              |   |       |
| Birkenhead . . .  | 16 v. 67             | -·239       | ..           | +·079 }                                     | +·027 | -·267       | ..           |   |       |
| " . . .   | 18 v. 67             | ..          | -·226        | $4^{\circ} 30'$ }                           | ..    | ..          | +·019        |   |       |
| Spithead . . .  | 18 vi. 67            | ..          | -·172        | ..  | ..    | ..          | +·004        |   |       |
| Simon's Bay, C.   |                      |             |              |   |       |             |              |   |       |
| Good Hope . . .   | 31 vii. 67           | ..          | -·159        | ..  | ..    | ..          | +·092        |   |       |
| Suez . . .  | 10 i. 68             | ..          | -·156        | ..  | ..    | ..          | +·097        |   |       |
| Spithead . . .  | 11 x. 71             | -·245       | ..           | ..  | ..    | -·089       | ..           |   |       |
| HIMALAYA.—Built . . . . . Distance of standard from stern 64 feet.  |                      |             |              |   |       |             |              |   |       |
| Spithead . . . . .  | 8 iii. 67            | -·077       | ..           | +·017 }                                     | +·007 | +·270       | ..           | +·015 }                                     | +·006 |
| " . . . . .   | 15 iii. 67           | ..          | -·048        | $+1^{\circ} 0'$ }                           | ..    | ..          | +·035        | $+0^{\circ} 52'$ }                          |       |
| Plymouth . . . . .  | 2 vii. 72            | ..          | -·030        | ..  | ..    | ..          | -·061        |   |       |
| Simon's Bay, C.   |                      |             |              |   |       |             |              |   |       |
| Good Hope . . . . .   | viii. 72             | ..          | -·030        | ..  | ..    | ..          | -·042        |   |       |
| Plymouth . . . . .  | 9 xi. 74             | ..          | -·021        | +·015 }                                     | +·006 | ..          | -·058        |   |       |
| Simon's Bay, C.   |                      |             |              |   |       |             |              |   |       |
| Good Hope . . . . .   | 18 i. 75             | ..          | -·021        | $+0^{\circ} 52'$ }                          | ..    | ..          | -·081        |   |       |
| Plymouth . . . . .  | 18 vi. 75            | ..          | -·031        | ..  | ..    | ..          | -·081        |   |       |
| ORONTES.—Built N. $68^{\circ}$ W. Distance of standard from stern 66 feet, from iron mast 9 feet.                 |                      |             |              |   |       |             |              |   |       |
| Birkenhead . . .  | 26 i. 76             | -·084       | ..           | +·074 }                                     | +·029 | -·202       | ..           |   |       |
| Spithead . . .  | 2 iii. 76            | ..          | -·042        | $+4^{\circ} 15'$ }                          | ..    | ..          | +·018        |   |       |
| " . . .   | 5 ix. 79             | ..          | -·058        | ..  | ..    | ..          | +·084        |   |       |
| Simon's Bay, C.   |                      |             |              |   |       |             |              |   |       |
| Good Hope . . .   | x. 79                | ..          | -·058        | ..  | ..    | ..          | +·034        |   |       |
| Mauritius . . .   | xi. 79               | ..          | -·044        | ..  | ..    | ..          | +·094        |   |       |

\* After re-correction by a permanent magnet.

TABLE I.—Values of the Constant Parameters P and  $c$ , Q and  $f$ , at Standard Compass Positions in Her Majesty's Ships (continued).

| Geographical position.  | Date of observation. | Original P. | Corrected P. | $\frac{c}{\lambda} \tan \theta$ in England. | $c$ . | Original Q. | Corrected Q. | $\frac{f}{\lambda} \tan \theta$ in England. | $f$ . |
|---|----------------------|-------------|--------------|---|-------|-------------|--------------|---|-------|
| <i>Steel and iron ships cased with wood.</i>  |                      |             |              |   |       |             |              |   |       |
| COMUS.—Built S. $11^{\circ}$ W. Distance of standard from stern 50 feet, from iron mast $7\frac{3}{4}$ feet.                  |                      |             |              |   |       |             |              |   |       |
| Sheerness . . .   | 14 xi. 79            | +·246       | ..           | +·089 }<br>=                                | +·034 | -·029       | ..           | -·010 }<br>=                                | -·004 |
| " . . .   | 18 xii. 79           | +·234       | +·009        | +5° 7' }                                    | ..    | +·041       | +·022        | -0° 35'                                     |       |
| Simon's Bay, C. Good Hope . .   | 20 iii. 80           | ..          | -·042        | ..  | ..    | ..          | +·038        |   |       |
| Hong Kong . .   | 12 vii. 80           | ..          | -·042        | ..  | ..    | ..          | +·038        |   |       |
| Singapore . . .   | 13 xii. 81           | ..          | -·017        | ..  | ..    | ..          | +·035        |   |       |
| CARYSFORT.—Built S. $11^{\circ}$ W. Distance of standard from stern 50 feet, from iron mast 7·9 feet.                         |                      |             |              |   |       |             |              |   |       |
| Sheerness . . .   | 5 x. 80              | +·262       | ..           | +·111 }                                     | +·044 | -·014       | ..           |   |       |
| " . . .   | 6 x. 80              | ..          | -·099        | +6° 23' }                                   | ..    | ..          | -·024        |   |       |
| Simon's Bay, C. Good Hope . .   | 1 iv. 81             | ..          | -·133        | ..  | ..    | ..          | +·030        |   |       |
| Kobé, Japan . .   | 10 xi. 81            | ..          | -·133        | ..  | ..    | ..          | +·007        |   |       |
| CLEOPATRA.—Built S. $11^{\circ}$ W. Distance of standard from stern $49\frac{1}{2}$ feet, from iron mast $6\frac{3}{4}$ feet. |                      |             |              |   |       |             |              |   |       |
| Plymouth . . .  | 15 ix. 80            | +·057       | ..           | +·082 }                                     | +·032 | +·050       | ..           |   |       |
| " . . .   | 17 ix. 80            | ..          | -·033        | +4° 43' }                                   | ..    | ..          | +·031        |   |       |
| Monte Video . .   | 31 xii. 80           | ..          | -·074        | ..  | ..    | ..          | -·028        |   |       |
| Hong Kong . .   | 20 xii. 81           | ..          | -·074        | ..  | ..    | ..          | +·039        |   |       |
| <i>Composite vessels.</i>   |                      |             |              |   |       |             |              |   |       |
| RUBY.—Built N. $3^{\circ}$ W. Distance of standard from stern 50 feet, from iron mast $6\frac{3}{4}$ feet.                    |                      |             |              |   |       |             |              |   |       |
| Sheerness . . .   | 30 vi. 77            | -·486       | ..           | +·077 }                                     | +·027 | -·109       | ..           |   |       |
| " . . .   | 3 vii. 77            | ..          | -·086        | +4° 25' }                                   | ..    | ..          | -·009        |   |       |
| Gulf of Xeros . .   | iii. 78              | ..          | -·083        | ..  | ..    | ..          | +·003        |   |       |
| Singapore . . .   | vi. 78               | ..          | -·083        | ..  | ..    | ..          | +·018        |   |       |
| Rangoon . . .   | x. 79                | ..          | -·101        | ..  | ..    | ..          | -·028        |   |       |
| Zanzibar . . .  | 12 iii. 80           | ..          | -·076        | ..  | ..    | ..          | -·009        |   |       |
| GANNET.*—Built S. $76^{\circ}$ E. Distance of standard from stern 38 feet.  |                      |             |              |   |       |             |              |   |       |
| Sheerness . . .   | 29 iv. 79            | +·122       | ..           | +·065 }                                     | +·024 | +·139       | ..           |   |       |
| " . . .   | 30 iv. 79            | ..          | -·012        | +3° 45' }                                   | ..    | ..          | +·010        |   |       |
| Coquimbo . . .  | x. 79                | ..          | -·059        | ..  | ..    | ..          | -·032        |   |       |
| Esquimalt, Vancouver Island . .   | vii. 81              | ..          | -·059        | ..  | ..    | ..          | -·014        |   |       |
| ALBATROSS.*—Built S. $50^{\circ}$ E. Distance of standard from stern $37\frac{1}{2}$ feet.                                    |                      |             |              |   |       |             |              |   |       |
| Sheerness . . .   | 17 xii. 73           | +·209       | ..           | +·073 }                                     | +0·29 | +·100       | ..           |   |       |
| " . . .   | 20 iii. 74           | ..          | -·066        | +4° 12' }                                   | ..    | ..          | +·015        |   |       |
| Rio de Janeiro . .  | 5 vii. 74            | ..          | -·066        | ..  | ..    | ..          | -·017        |   |       |
| Plymouth . . .  | 10 x. 74             | ..          | -·064        | ..  | ..    | ..          | +·022        |   |       |
| Taboga . . .  | 27 x. 75             | ..          | -·091        | ..  | ..    | ..          | -·006        |   |       |
| Pisco . . .   | 15 xii. 76           | ..          | -·093        | ..  | ..    | ..          | +·002        |   |       |
| Esquimalt, Vancouver Island . .   | 29 x. 77             | ..          | -·093        | ..  | ..    | ..          | +·016        |   |       |

\* These vessels have wooden masts.

TABLE I.—Values of the Constant Parameters P and  $c$ , Q and  $f$ , at Standard Compass Positions in Her Majesty's Ships (continued).

| Geographical position.  | Date of observation. | Original P. | Corrected P.   | $\frac{c}{\lambda} \tan \theta$ in England. | $c$ .   | Original Q. | Corrected Q.   | $\frac{f}{\lambda} \tan \theta$ in England. | $f$ . |
|---|----------------------|-------------|----------------|---|---------|-------------|----------------|---|-------|
| <i>Composite vessels (continued).</i>   |                      |             |                |   |         |             |                |   |       |
| BOXER.*—Built S. $60^{\circ}$ W. Distance of standard from stern $30\frac{1}{2}$ feet.                          |                      |             |                |   |         |             |                |   |       |
| Greenhithe . . .  | 30 xi. 68            | +·124       | -·004          | +·062 }<br>=                                | +·023 } | -·150       | -·022          |   |       |
| Rio de Janeiro . . .  | 20 ii. 69            | ..          | -·016          | + $3^{\circ} 35'$ }                         | ..      | ..          | -·105          |   |       |
| Esquimault, Vancouver's Island . . .  | 5 x. 69              | ..          | -·008          | ..  | ..      | ..          | -·049          |   |       |
| Komax, Vancouver's Island . . .   | 24 iv. 71            | ..          | -·029          | ..  | ..      | ..          | -·058          |   |       |
| Esquimault . . .  | 30 xii. 74           | ..          | -·004          | ..  | ..      | ..          | -·030          |   |       |
| Coquimbo . . .  | 13 v. 75             | ..          | -·004          | ..  | ..      | ..          | -·003          |   |       |
| PERT.*—Built S. $65^{\circ}$ W. Distance of standard from stern $29\frac{3}{4}$ feet.                           |                      |             |                |   |         |             |                |   |       |
| Devonport . . .   | 3 ii. 70             | +·170       | ..             | +·070 }<br>=                                | +·026 } | -·174       | ..             |   |       |
| " . . .   | 8 ii. 70             | ..          | -·056          | + $4^{\circ} 0'$ }                          | ..      | ..          | -·016          |   |       |
| Elephant Bay, W. C. Africa . . .  | 29 xii. 70           | ..          | -·056          | ..  | ..      | ..          | -·051          |   |       |
| Rio de Janeiro . . .  | 29 xii. 71           | ..          | -·043          | ..  | ..      | ..          | -·054          |   |       |
| FIREFLY.*—Built N. $26^{\circ}$ E. Distance of standard from stern $15\frac{3}{4}$ feet.                        |                      |             |                |   |         |             |                |   |       |
| Plymouth . . .  | 24 vi. 79            | -·332       | +·004          | +·012 }<br>=                                | +·005 } | ..          | +·015          |   |       |
| Simon's Bay, C. Good Hope . . .   | 29 v. 80             | ..          | +·004          | + $0^{\circ} 42'$ }                         | ..      | ..          | +·001          |   |       |
| Gaboon River, W. C. Africa . . .  | 30 viii. 80          | ..          | +·032          | ..  | ..      | ..          | +·046          |   |       |
| WRANGLER.*—Built N. $45^{\circ}$ E. Distance of standard from stern $15\frac{3}{4}$ feet.                       |                      |             |                |   |         |             |                |   |       |
| Plymouth . . .  | 26 v. 81             | -·183       | -·017          | +·006 }<br>=                                | +·002 } | +·323       | +·004          |   |       |
| Simon's Bay, C. Good Hope . . .   | 31 xii. 81           | ..          | -·017          | + $0^{\circ} 20'$ }                         | ..      | ..          | +·027          |   |       |
| <i>Wooden corvettes with iron beams and iron vertical bulkheads from keel to lower deck.</i>                    |                      |             |                |   |         |             |                |   |       |
| ENCOUNTER.—Built S. $76^{\circ}$ E. Distance of standard from stern 48 feet. Masts wooden.                      |                      |             |                |   |         |             |                |   |       |
| Sheerness . . .   | 2 ix. 73             | +·182       | ..             | +·046 }<br>=                                | +·018 } | +·148       | ..             |   |       |
| " . . .   | 9 ix. 73             | ..          | +·016          | + $2^{\circ} 40'$ }                         | ..      | ..          | +·034          |   |       |
| Simon's Bay, C. Good Hope . . .   | 11 iv. 74            | ..          | +·002          | ..  | ..      | ..          | +·022          |   |       |
| " . . .   | 15 x. 74             | ..          | -·002          | ..  | ..      | ..          | +·007          |   |       |
| " . . .   | 20 i. 76             | ..          | -·048          | ..  | ..      | ..          | -·001          |   |       |
| Grenada . . .   | 30 x. 76             | ..          | -·048          | ..  | ..      | ..          | -·014          |   |       |
| SAPPHIRE.—Built East. Distance of standard from stern $47\frac{3}{4}$ feet, from iron mast $5\frac{1}{2}$ feet. |                      |             |                |   |         |             |                |   |       |
| Plymouth . . .  | 21 viii. 75          | +·202       | ..             | +·117 }<br>=                                | +·045 } | +·115       | ..             |   |       |
| " . . .   | 24 viii. 75          | ..          | -·093          | + $6^{\circ} 45'$ }                         | ..      | ..          | +·012          |   |       |
| Simon's Bay, C. Good Hope . . .   | 30 xi. 75            | ..          | -·093          | ..  | ..      | ..          | +·013          |   |       |
| Wellington, N.Z. Sydney, N.S.W.   | xii. 76 viii. 77     | ..          | -·107<br>-·152 | ..  | ..      | ..          | +·001<br>-·033 |   |       |

\* These vessels have wooden masts.

TABLE II.--Table of Terrestrial Magnetic Elements for the Year 1880,  
used in the computations.

| Geographical position.                  | Inclination<br>$\theta.$ | Approximate<br>annual change. | Absolute<br>horizontal force in<br>British units. | Approximate<br>annual change. |
|---|--------------------------|-------------------------------|---|-------------------------------|
| Greenwich . . . . .                     | +67 36                   | - 1·7                         | 3·915   | +·005                         |
| Gibraltar . . . . .                     | +55 43                   | - 4·5                         | 5·259   | +·007                         |
| Maderia . . . . .                       | +56 0                    | - 5·0                         | 5·282   | +·006                         |
| Gaboon River . . . . .                  | -15 0                    | -12·0                         | 6·50  | -·012                         |
| Elephant Bay . . . . .                  | -39 12                   | ..                            | 5·40  | ..                            |
| Simon's Bay, C. Good Hope . . . . .     | -56 28                   | - 5·0                         | 4·270   | -·007                         |
| Quebec . . . . .                        | +77 0                    | ..                            | 2·97  | ..                            |
| Rimouski . . . . .                      | +77 52                   | ..                            | 2·85  | ..                            |
| Halifax, N.S. . . . .                   | +74 48                   | - 1·8                         | 3·388   | +·002                         |
| Bermuda . . . . .                       | +65 0                    | ..                            | 5·115   | +·002                         |
| St. Lucia . . . . .                     | +43 50                   | ..                            | 6·75  | ..                            |
| Dominica . . . . .                      | +45 48                   | ..                            | 6·67  | ..                            |
| Grenada . . . . .                       | +41 20                   | ..                            | 6·85  | ..                            |
| Trinidad . . . . .                      | +39 40                   | ..                            | 6·89  | ..                            |
| Rio de Janeiro . . . . .                | -10 46                   | + 3·0                         | 5·66  | -·016                         |
| Monte Video . . . . .                   | -29 10                   | + 8·5                         | 5·745   | -·017                         |
| Sandy Point, Magellan Straits . . . . . | -52 20                   | +11·0                         | 6·056   | -·004                         |
| 27½° N., 62½° W. . . . .                | +60 0                    | ..                            | 5·70  | ..                            |
| Equator, and 24½° W. . . . .            | +15 7                    | - 9·0                         | 6·40  | -·007                         |
| 23° S., 39° W. . . . .                  | -11 52                   | + 2·0                         | 5·51  | -·016                         |
| 40½° S., 78¾° W. . . . .                | -44 8                    | ..                            | 6·20  | ..                            |
| 1° S., 26° W. . . . .                   | +16 42                   | - 9·0                         | 6·40  | -·007                         |
| Valparaiso . . . . .                    | -33 39                   | + 5·0                         | 6·078   | -·018                         |
| Coquimbo . . . . .                      | -29 12                   | + 4·0                         | 6·14  | -·017                         |
| Pisco . . . . .                         | - 7 44                   | ..                            | 6·69  | -·013                         |
| Panama . . . . .                        | +31 57                   | ..                            | 7·560   | -·004                         |
| Esquimalt, Vancouver Island . . . . .   | +71 54                   | ..                            | 4·21  | ..                            |
| 9½ S., 80¾° W. . . . .                  | -- 3 15                  | ..                            | 7·0   | ..                            |
| 20 N., 157° W. . . . .                  | +37 58                   | ..                            | 6·64  | ..                            |
| Komax, Vancouver Island . . . . .       | +71 37                   | ..                            | 4·27  | ..                            |
| Gulf of Xeros. . . . .                  | +55 23                   | ..                            | 5·49  | ..                            |
| Suez . . . . .                          | +40 47                   | - 1·0                         | 6·50  | ..                            |
| Zanzibar . . . . .                      | -36 0                    | ..                            | 6·205   | ..                            |
| Mauritius . . . . .                     | -56 23                   | - 1·0                         | 5·158   | -·002                         |
| Bombay . . . . .                        | +19 29                   | + 1·2                         | 8·10  | +·003                         |
| Rangoon . . . . .                       | +17 44                   | ..                            | 8·15  | ..                            |
| 6° N., 96° E. . . . .                   | - 5 10                   | ..                            | 8·30  | ..                            |
| Singapore . . . . .                     | -13 11                   | - 0·2                         | 8·251   | +·004                         |
| Hong Kong . . . . .                     | +32 40                   | + 4·2                         | 7·794   | +·006                         |
| Yokohama . . . . .                      | +49 12                   | + 3·4                         | 6·417   | ..                            |
| Kobé, Japan . . . . .                   | +48 48                   | + 3·5                         | 6·56  | ..                            |
| Simonoseki . . . . .                    | +48 40                   | + 4·0                         | 6·64  | ..                            |
| 49° N., 149° E. . . . .                 | +62 30                   | ..                            | 5·00  | ..                            |
| 38° N., 136° E. . . . .                 | +53 5                    | ..                            | 6·19  | ..                            |
| 34° N., 133½° E. . . . .                | +46 8                    | ..                            | 6·60  | ..                            |
| 12½° N., 46° E. . . . .                 | + 5 52                   | ..                            | 7·50  | ..                            |
| Melbourne . . . . .                     | -67 5                    | Stationary                    | 5·117   | -·002                         |
| Sydney, N.S.W. . . . .                  | -62 44                   | Stationary                    | 5·754   | -·003                         |
| Wellington, N.Z. . . . .                | -65 12                   | - 1·0                         | 5·266   | ..                            |

The + sign indicates north inclination or dip, the - sign that of south dip. The correction for annual change of the inclination or dip is to be applied algebraically.

TABLE III.—Coefficients.

| Place.   | Date.        | Approximate coefficients.                                |         |         |         |         |         | Exact coefficients. |         |         |         |         |         | Coefficients of horizontal induction. | Part of $\mathfrak{D}$ from | Heeling coefficient for windward. | Heeling coefficient to windward. | Vertical force and induction in transverse iron. | $\frac{g}{\tan \theta} \cdot g$ . |     |  |  |  |  |  |  |
|--|--------------|--|---------|---------|---------|---------|---------|---------------------|---------|---------|---------|---------|---------|---------------------------------------|-----------------------------|-----------------------------------|----------------------------------|--|-----------------------------------|-----|--|--|--|--|--|--|
|  |              |  |         |         |         |         |         |                     |         |         |         |         |         |                                       |                             |                                   |                                  |  |                                   |     |  |  |  |  |  |  |
|  |              | A.   | B.      | C.      | D.      | E.      | F.      | G.                  | H.      | I.      | J.      | K.      | L.      |                                       |                             |                                   |                                  |  |                                   |     |  |  |  |  |  |  |
| BELLEROPHON.—Iron screw ship, armour-plated; 7550 tons; 6520 H.P.; 13 guns. Built, Chatham; head S., 51° E.; launched, 3 iii. 66.—Standard Compass.            |              |  |         |         |         |         |         |                     |         |         |         |         |         |                                       |                             |                                   |                                  |  |                                   |     |  |  |  |  |  |  |
| Spithead   | 8 vii. 73    | From quadrant.   | ...     | ...     | ...     | ...     | ...     | +0.028              | +0.233  | +0.098  | ...     | ...     | ...     | ...                                   | ...                         | ...                               | ...                              | ...  | ...                               | ... |  |  |  |  |  |  |
|  | 4 xi. 73     | + 1 11 - 0 16 + 1 3 + 5 12 - 0 32                        | + 0.020 | + 0.05  | + 0.017 | + 0.020 | - 0.002 | + 0.041             | - 0.014 | + 0.107 | - 0.009 | ...     | ...     | ...                                   | ...                         | ...                               | ...                              | ...  | ...                               | ... |  |  |  |  |  |  |
| Halifax, N.S.  | 5 viii. 74   | - 0 8 + 2 20 - 6 9                                       | - 0.023 | - 0.005 | - 0.023 | - 0.011 | - 0.011 | - 0.033             | - 0.042 | + 0.082 | + 0.026 | ...     | ...     | ...                                   | ...                         | ...                               | ...                              | ...  | ...                               | ... |  |  |  |  |  |  |
| Quebec   | 16 ix. 74    | - 0 38 - 0 11 - 2 26 + 5 16 + 1 30                       | - 0.026 | - 0.011 | - 0.026 | - 0.011 | - 0.011 | - 0.031             | - 0.045 | + 0.083 | + 0.026 | ...     | ...     | ...                                   | ...                         | ...                               | ...                              | ...  | ...                               | ... |  |  |  |  |  |  |
| Trinidad   | 1 iii. 76    | + 0 1 - 0 45 - 0 21 + 5 39 + 0 26 + 0 01                 | - 0.026 | - 0.011 | - 0.026 | - 0.011 | - 0.011 | - 0.031             | - 0.045 | + 0.083 | + 0.026 | ...     | ...     | ...                                   | ...                         | ...                               | ...                              | ...  | ...                               | ... |  |  |  |  |  |  |
| Halifax, N.S.  | 21 vi. 76    | - 0 28 - 1 30 - 1 35 - 6 11 - 0 37 - 0 08                | - 0.026 | - 0.011 | - 0.026 | - 0.011 | - 0.011 | - 0.031             | - 0.045 | + 0.083 | + 0.026 | ...     | ...     | ...                                   | ...                         | ...                               | ...                              | ...  | ...                               | ... |  |  |  |  |  |  |
| Quebec   | 24 viii. 76  | - 0 13 - 1 40 - 1 25 + 4 39 + 0 39                       | - 0.026 | - 0.011 | - 0.026 | - 0.011 | - 0.011 | - 0.031             | - 0.045 | + 0.083 | + 0.026 | ...     | ...     | ...                                   | ...                         | ...                               | ...                              | ...  | ...                               | ... |  |  |  |  |  |  |
| IRON DUCHESS.—Iron double screw ship, armour-plated; 6010 tons; 4270 H.P.; 14 guns. Built at Pembroke; head S., 39° W.; launched, 1 iii. 70.—Standard Compass. |              |  |         |         |         |         |         |                     |         |         |         |         |         |                                       |                             |                                   |                                  |  |                                   |     |  |  |  |  |  |  |
| Plymouth   | 20 i. 71     | + 0 65 + 34 18 - 11 24 + 5 45 + 0 46                     | + 0.116 | + 0.598 | - 0.180 | + 0.100 | + 0.113 | ...                 | ...     | ...     | ...     | ...     | ...     | ...                                   | ...                         | ...                               | ...                              | ...  | ...                               | ... |  |  |  |  |  |  |
|  | 16 ix. 71    | + 1 9 + 7 31 + 3 11 + 6 23 - 0 2                         | + 0.020 | + 0.057 | + 0.017 | + 0.020 | + 0.009 | + 0.020             | + 0.048 | + 0.089 | + 0.011 | + 0.007 | + 0.014 | + 0.001                               | + 0.001                     | + 0.001                           | + 0.001                          | + 0.001  | + 0.001                           |     |  |  |  |  |  |  |
| Gibraltar  | 10 xii. 71   | + 0 13 + 3 32 - 0 23 + 6 0                               | + 0.020 | + 0.057 | + 0.017 | + 0.020 | + 0.009 | + 0.020             | + 0.048 | + 0.089 | + 0.011 | + 0.007 | + 0.014 | + 0.001                               | + 0.001                     | + 0.001                           | + 0.001                          | + 0.001  | + 0.001                           |     |  |  |  |  |  |  |
| 6° N., 96° E.  | 22 xii. 72   | + 0 59 + 2 57 + 5 40 + 0 39                              | + 0.020 | + 0.057 | + 0.017 | + 0.020 | + 0.009 | + 0.020             | + 0.048 | + 0.089 | + 0.011 | + 0.007 | + 0.014 | + 0.001                               | + 0.001                     | + 0.001                           | + 0.001                          | + 0.001  | + 0.001                           |     |  |  |  |  |  |  |
| 38° N., 138° E.  | 27 viii. 73  | + 0 53 + 1 22 + 1 27 + 4 48 - 0 10                       | + 0.020 | + 0.057 | + 0.017 | + 0.020 | + 0.009 | + 0.020             | + 0.048 | + 0.089 | + 0.011 | + 0.007 | + 0.014 | + 0.001                               | + 0.001                     | + 0.001                           | + 0.001                          | + 0.001  | + 0.001                           |     |  |  |  |  |  |  |
| 49° N., 140° E.  | 11 iii. 73   | + 0 25 - 3 23 - 0 36 + 5 3 + 0 34                        | + 0.020 | + 0.057 | + 0.017 | + 0.020 | + 0.009 | + 0.020             | + 0.048 | + 0.089 | + 0.011 | + 0.007 | + 0.014 | + 0.001                               | + 0.001                     | + 0.001                           | + 0.001                          | + 0.001  | + 0.001                           |     |  |  |  |  |  |  |
| 34° N., 133° E.  | 27 vii. 74   | + 0 30 + 2 26 + 1 26 + 4 45 + 1 13                       | + 0.020 | + 0.057 | + 0.017 | + 0.020 | + 0.009 | + 0.020             | + 0.048 | + 0.089 | + 0.011 | + 0.007 | + 0.014 | + 0.001                               | + 0.001                     | + 0.001                           | + 0.001                          | + 0.001  | + 0.001                           |     |  |  |  |  |  |  |
| 12° N., 46° E.   | 27 vii. 75   | + 0 12 + 0 38 + 2 45 + 4 47 + 1 13                       | + 0.020 | + 0.057 | + 0.017 | + 0.020 | + 0.009 | + 0.020             | + 0.048 | + 0.089 | + 0.011 | + 0.007 | + 0.014 | + 0.001                               | + 0.001                     | + 0.001                           | + 0.001                          | + 0.001  | + 0.001                           |     |  |  |  |  |  |  |
| Plymouth*  | 5 ix. 75     | - 0 27 + 1 0 + 2 45 + 7 16 + 0 7                         | - 0.007 | - 0.017 | - 0.017 | - 0.017 | - 0.007 | - 0.017             | - 0.028 | - 0.074 | - 0.007 | - 0.017 | - 0.017 | - 0.002                               | - 0.002                     | - 0.002                           | - 0.002                          | - 0.002  | - 0.002                           |     |  |  |  |  |  |  |
| Belfast Lough  | 18 vii. 78   | From four cardinal points.                               | ...     | ...     | ...     | ...     | ...     | ...                 | ...     | ...     | ...     | ...     | ...     | ...                                   | ...                         | ...                               | ...                              | ...  | ...                               | ... |  |  |  |  |  |  |
| Plymouth   | 11 vii. 78   | + 0 8 + 1 26 - 1 26 + 0 21 + 0 21                        | + 0.020 | + 0.057 | + 0.017 | + 0.020 | + 0.009 | + 0.020             | + 0.048 | + 0.089 | + 0.011 | + 0.007 | + 0.014 | + 0.001                               | + 0.001                     | + 0.001                           | + 0.001                          | + 0.001  | + 0.001                           |     |  |  |  |  |  |  |
| Singapore  | vii. 79      | + 0 1 - 6 17 + 1 7 + 4 56 + 0 14                         | + 0.020 | + 0.057 | + 0.017 | + 0.020 | + 0.009 | + 0.020             | + 0.048 | + 0.089 | + 0.011 | + 0.007 | + 0.014 | + 0.001                               | + 0.001                     | + 0.001                           | + 0.001                          | + 0.001  | + 0.001                           |     |  |  |  |  |  |  |
| Yokohama   | 28 xii. 80   | - 0 46 - 3 57 - 0 2 + 5 62 + 0 34                        | - 0.026 | - 0.011 | - 0.026 | - 0.011 | - 0.011 | - 0.026             | - 0.065 | - 0.113 | - 0.026 | - 0.011 | - 0.016 | - 0.006                               | - 0.006                     | - 0.006                           | - 0.006                          | - 0.006  | - 0.006                           |     |  |  |  |  |  |  |
| Hong Kong  | 31 xii. 81   | - 1 8 - 3 35 - 1 12 + 4 23 + 0 49                        | - 0.026 | - 0.011 | - 0.026 | - 0.011 | - 0.011 | - 0.026             | - 0.065 | - 0.113 | - 0.026 | - 0.011 | - 0.016 | - 0.006                               | - 0.006                     | - 0.006                           | - 0.006                          | - 0.006  | - 0.006                           |     |  |  |  |  |  |  |
| TRIUMPH.—Iron screw ship, armour-plated; 6640 tons; 5110 H.P.; 14 guns. Built on River Tyne; head S., 45° W.; launched, 29 ix. 70.—Standard Compass.           |              |  |         |         |         |         |         |                     |         |         |         |         |         |                                       |                             |                                   |                                  |  |                                   |     |  |  |  |  |  |  |
| Plymouth   | 18 iii. 73   | - 1 9 + 20 53 - 10 0 + 6 45 - 0 5                        | - 0.020 | + 0.377 | - 0.161 | + 0.117 | - 0.001 | ...                 | ...     | ...     | ...     | ...     | ...     | ...                                   | ...                         | ...                               | ...                              | ...  | ...                               | ... |  |  |  |  |  |  |
| Spithead   | 15 v. 78     | + 0 18 + 1 40 - 0 23 + 7 12 + 0 33                       | + 0.020 | + 0.377 | - 0.161 | + 0.117 | - 0.001 | ...                 | ...     | ...     | ...     | ...     | ...     | ...                                   | ...                         | ...                               | ...                              | ...  | ...                               | ... |  |  |  |  |  |  |
| "  | "            | From S.W. quadrant.                                      | ...     | ...     | ...     | ...     | ...     | ...                 | ...     | ...     | ...     | ...     | ...     | ...                                   | ...                         | ...                               | ...                              | ...  | ...                               | ... |  |  |  |  |  |  |
| Equator  | 24° W. long. | - 1 23 - 2 7 + 0 51 + 5 51                               | - 0.020 | - 0.344 | - 0.039 | - 0.039 | - 0.001 | ...                 | ...     | ...     | ...     | ...     | ...     | ...                                   | ...                         | ...                               | ...                              | ...  | ...                               | ... |  |  |  |  |  |  |
| 23° S., 39° W.   | 20 vi. 78    | - 2 29 - 7 0 - 0 56 + 7 6 - 0 58                         | - 0.020 | - 0.343 | - 0.039 | - 0.039 | - 0.001 | ...                 | ...     | ...     | ...     | ...     | ...     | ...                                   | ...                         | ...                               | ...                              | ...  | ...                               | ... |  |  |  |  |  |  |
| 40° S., 73° W.   | 1 vii. 78    | - 3 31 - 11 13 + 0 38 + 6 41 - 0 44                      | - 0.020 | - 0.343 | - 0.039 | - 0.039 | - 0.001 | ...                 | ...     | ...     | ...     | ...     | ...     | ...                                   | ...                         | ...                               | ...                              | ...  | ...                               | ... |  |  |  |  |  |  |
| Vallparaiso  | ix. x. 78    | - 0 49 - 14 51 + 0 55 + 6 39 - 1 19 + 0 14 + 6 30 - 0 20 | - 0.020 | - 0.343 | - 0.039 | - 0.039 | - 0.001 | ...                 | ...     | ...     | ...     | ...     | ...     | ...                                   | ...                         | ...                               | ...                              | ...  | ...                               | ... |  |  |  |  |  |  |
| 9° S., 80° W.  | 7 vii. 78    | - 0 29 - 12 14 + 0 14 + 6 30 - 0 20 + 6 30 - 0 20        | - 0.020 | - 0.343 | - 0.039 | - 0.039 | - 0.001 | ...                 | ...     | ...     | ...     | ...     | ...     | ...                                   | ...                         | ...                               | ...                              | ...  | ...                               | ... |  |  |  |  |  |  |
| 20° N., 157° W.  | 4 iv. 79     | - 1 31 - 7 28 - 0 57 + 6 55 + 0 18 + 6 55 - 0 42         | - 0.020 | - 0.343 | - 0.039 | - 0.039 | - 0.001 | ...                 | ...     | ...     | ...     | ...     | ...     | ...                                   | ...                         | ...                               | ...                              | ...  | ...                               | ... |  |  |  |  |  |  |
| Esquimalt  | 7 vii. 79    | ...  | ...     | ...     | ...     | ...     | ...     | ...                 | ...     | ...     | ...     | ...     | ...     | ...                                   | ...                         | ...                               | ...                              | ...  | ...                               | ... |  |  |  |  |  |  |

\* After repair at Birkenhead. Compass re-corrected at Plymouth.

† Compass re-corrected on this day.

Note.—The values of B. and C. &c., printed in italics have been computed from the tables of deviation observed after the compass had been corrected by magnets.

TABLE III.—Coefficients (continued).

| Place.   | Date.       | Approximate coefficients.                 |          |       |       |        |        | Exact coefficients. |       |        |        |        |        | Maximum of semi-circular deviation.<br>$\sqrt{B^2 + C^2}$ | Mean force of ship.<br>$\sqrt{B^2 + C^2}$ | Mean force to north.<br>λ | Coefficients of horizontal induction.<br>$\sqrt{B^2 + C^2}$ | Part of $\mathfrak{D}$ from |                | Heeling coefficient for<br>vertical force and induction in transverse iron. | Heeling coefficient for<br>vertical force and induction in vertical iron. | Variable part of vertical force. |       |       |       |       |       |       |
|--|-------------|---|----------|-------|-------|--------|--------|---------------------|-------|--------|--------|--------|--------|---|---|---------------------------|---|-----------------------------|----------------|---|---|----------------------------------|-------|-------|-------|-------|-------|-------|
|  |             | A.  | B.       | C.    | D.    | E.     | F.     | G.                  | H.    | I.     | J.     | K.     | L.     |   |   |                           | λ   | Head-ward.                  | To star-board. | a.  | e.  |                                  |       |       |       |       |       |       |
| <i>Iron armour-plated ships (continued).</i>   |             |   |          |       |       |        |        |                     |       |        |        |        |        |   |   |                           |   |                             |                |   |   |                                  |       |       |       |       |       |       |
| SWIFTSURE.—Iron, screw ship, armour plated; 6910 tons; 4910 H.P.; 18 guns. Built on River Tyne; head S., 56° W.; launched, 15 vi. 70.—Standard Compass.            |             |   |          |       |       |        |        |                     |       |        |        |        |        |   |   |                           |   |                             |                |   |   |                                  |       |       |       |       |       |       |
| Plymouth . . . . .   | 17 vii. 72  | From N. & W. semi-circles.                | 0.441+20 | 1     | -0.37 | +3.38  | -0     | 6                   | -0.13 | +354   | -0.10  | +0.03  | -0.02  | 20  | '834                                      | 1.199                     | -0.064  | -298                        | -2             | 11  | +1.21   | +0.48                            | +0.33 | +0.62 | +1.15 |       |       |       |
| " . . . . .  | 8 v. 82     | From N.E. quadrant.                       | 0.37+    | 0     | 1     | -0.6   | +4     | 3                   | -0    | 1      | +0.11  | +0.04  | -0.02  | +0.01   | '834                                      | 1.199                     | -0.064  | -298                        | -2             | 11  | +1.21   | +0.48                            | +0.33 | +0.62 | +1.15 |       |       |       |
| " . . . . .  | 22 vii. 82  | +0.33+2                                   | 0.22     | -0.22 | +6.12 | -0.22  | +0.09  | +0.03               | -0.06 | +1.08  | +0.06  | -0.03  | -0.02  | 20  | '834                                      | 1.199                     | -0.064  | -298                        | -2             | 11  | +1.21   | +0.48                            | +0.33 | +0.62 | +1.15 |       |       |       |
| 1° S., 26° W. . . . .  | 23 vii. 82  | +1.5                                      | -5       | 0.13  | +6.19 | +0.46  | +0.19  | -0.04               | +0.10 | +0.04  | -0.03  | -0.02  | -0.01  | 20  | '834                                      | 1.199                     | -0.064  | -298                        | -2             | 11  | +1.21   | +0.48                            | +0.33 | +0.62 | +1.15 |       |       |       |
| 23° S., 43° W. . . . .   | 5 viii. 82  | -4  | 11       | -8    | -4.10 | +5.44  | +0.17  | -0.07               | -0.20 | +0.05  | -0.04  | -0.03  | -0.02  | 20  | '834                                      | 1.199                     | -0.064  | -298                        | -2             | 11  | +1.21   | +0.48                            | +0.33 | +0.62 | +1.15 |       |       |       |
| Monte Video . . . . .  | 23 viii. 82 | -3  | 31       | -14   | 6     | -1.40  | +4.49  | -0                  | 9     | -0.61  | -0.25  | -0.08  | -0.02  | 20  | '834                                      | 1.199                     | -0.064  | -298                        | -2             | 11  | +1.21   | +0.48                            | +0.33 | +0.62 | +1.15 |       |       |       |
| Sandy Point, Magellan Straits . . . . .  | 4 viii. 92  | -1  | 54       | -18   | 32    | -1     | 7      | +6                  | 3     | -1.34  | -0.33  | -0.33  | -0.33  | 20  | '834                                      | 1.199                     | -0.064  | -298                        | -2             | 11  | +1.21   | +0.48                            | +0.33 | +0.62 | +1.15 |       |       |       |
| <i>NORTHAMPTON.—Iron double screw ship, armour plated; 7630 tons; 6070 H.P.; 12 guns. Built at Glasgow; head S., 6° E.; launched, 18 xi. 76.—Standard Compass.</i> |             |   |          |       |       |        |        |                     |       |        |        |        |        |   |   |                           |   |                             |                |   |   |                                  |       |       |       |       |       |       |
| Sheerness . . . . .  | 1 xi. 79    | -0.441+20                                 | 1        | -0.37 | +3.38 | -0     | 6      | -0.13               | +354  | -0.10  | +0.03  | -0.02  | 20     | '834  | 1.199                                     | -0.064                    | -298  | -2                          | 11             | +1.21   | +0.48   | +0.33                            | +0.62 | +1.15 |       |       |       |       |
| Southend . . . . .   | 18 xii. 79  | +0.37+                                    | 0        | 1     | -0.6  | +4     | 3      | -0                  | 1     | +0.11  | +0.04  | -0.02  | -0.01  | 20  | '834                                      | 1.199                     | -0.064  | -298                        | -2             | 11  | +1.21   | +0.48                            | +0.33 | +0.62 | +1.15 |       |       |       |
| 2½ N., 30° W. . . . .  | 23 i. 80    | +1  | 13       | +0    | 21    | -2     | 39     | +3                  | 44    | -0     | 16     | +0.21  | +0.06  | -0.04   | -0.03                                     | 20                        | '834  | 1.199                       | -0.064         | -298  | -2  | 11                               | +1.21 | +0.48 | +0.33 | +0.62 | +1.15 |       |
| St. Lucia, S.W. Point . . . . .  | 8 v. 80     | +0.58                                     | -1.53    | +1.12 | -3    | 4      | 0      | 22                  | +0.22 | -0.04  | +0.04  | -0.03  | -0.02  | 20  | '834                                      | 1.199                     | -0.064  | -298                        | -2             | 11  | +1.21   | +0.48                            | +0.33 | +0.62 | +1.15 |       |       |       |
| Bermuda . . . . .  | 27 vi. 80   | +0.36                                     | -3       | 10    | -3    | 2      | 3      | 40                  | -1.32 | +0.10  | -0.04  | -0.03  | -0.02  | 20  | '834                                      | 1.199                     | -0.064  | -298                        | -2             | 11  | +1.21   | +0.48                            | +0.33 | +0.62 | +1.15 |       |       |       |
| Halifax, N.S. . . . .  | 31 viii. 80 | -1  | 38       | -2    | 17    | -4     | 32     | +3                  | 42    | -0     | 31     | -0.28  | -0.04  | -0.03   | -0.02                                     | 20                        | '834  | 1.199                       | -0.064         | -298  | -2  | 11                               | +1.21 | +0.48 | +0.33 | +0.62 | +1.15 |       |
| Rinoussi River, St. Lawrence . . . . .   | 1 xi. 80    | -1  | 1        | -2    | 32    | -4     | 30     | -0                  | 15    | -0.18  | -0.04  | -0.03  | -0.02  | 20  | '834                                      | 1.199                     | -0.064  | -298                        | -2             | 11  | +1.21   | +0.48                            | +0.33 | +0.62 | +1.15 |       |       |       |
| Dominica . . . . .   | 22 i. 81    | -1  | 37       | +0    | 23    | -4     | 10     | +4                  | 1     | -0     | 18     | -0.28  | -0.07  | -0.03   | -0.02                                     | 20                        | '834  | 1.199                       | -0.064         | -298  | -2  | 11                               | +1.21 | +0.48 | +0.33 | +0.62 | +1.15 |       |
| <i>NELSON.—Iron, double screw ship, armour plated; 7630 tons; 6640 H.P.; 12 guns. Built at Glasgow; head S., 21° E.; launched 4 xi. 76.—Standard Compass.</i>      |             |   |          |       |       |        |        |                     |       |        |        |        |        |   |   |                           |   |                             |                |   |   |                                  |       |       |       |       |       |       |
| Sheerness . . . . .  | 28 vii. 81  | 0   | 31+16    | 38    | -4    | 7      | +4     | 0                   | +7    | -0.01  | +296   | -0.07  | +0.02  | -0.01   | 17  | '835                      | 1.305   | -0.064                      | -298           | -2  | 11  | +1.21                            | +0.48 | +0.33 | +0.62 | +1.15 |       |       |
| Plymouth . . . . .   | 28 ix. 81   | -0  | 23       | -0    | 13    | -0     | 5      | -0                  | 0     | -0.07  | -0.04  | -0.03  | -0.02  | 17  | '835                                      | 1.305                     | -0.064  | -298                        | -2             | 11  | +1.21   | +0.48                            | +0.33 | +0.62 | +1.15 |       |       |       |
| Madeira . . . . .  | 11 x. 81    | -0  | 6        | +0    | 055   | +0     | 51     | -0                  | 47    | -0     | 24     | -0.02  | +0.05  | -0.06   | -0.07                                     | 17                        | '835  | 1.305                       | -0.064         | -298  | -2  | 11                               | +1.21 | +0.48 | +0.33 | +0.62 | +1.15 |       |
| Simon's Bay, C. Good Hope . . . . .  | 14 xi. 81   | -0  | 44       | +4    | 35    | +2     | 34     | +3                  | 37    | -0     | 12     | -0.13  | +0.02  | +0.04   | +0.03                                     | 17                        | '835  | 1.305                       | -0.064         | -298  | -2  | 11                               | +1.21 | +0.48 | +0.33 | +0.62 | +1.15 |       |
| <i>ACRIVE.—Iron cased with wood; 3080 tons; 4130 H.P.; 12 guns. Built at Blackwall; head N., 33° E.; launched, 13 ii. 69.—Standard Compass.</i>                    |             |   |          |       |       |        |        |                     |       |        |        |        |        |   |   |                           |   |                             |                |   |   |                                  |       |       |       |       |       |       |
| Portsmouth . . . . .   | 28 ii. 70   | { From deviation and force on one point } |          |       |       | -0.540 | -0.085 | ass.                | ...   | -0.540 | -0.085 | -0.070 | -0.02  | 32  | '836                                      | 1.317                     | -0.064  | -298                        | -2             | 11  | +1.21   | +0.48                            | +0.33 | +0.62 | +1.15 |       |       |       |
| " . . . . .  | 7 iii. 70   | -0  | 10       | -2    | 35    | +0     | 42     | +4                  | 0     | -0     | 8      | -0.008 | -0.046 | +0.012  | -0.016                                    | 32                        | '836  | 1.317                       | -0.064         | -298  | -2  | 11                               | +1.21 | +0.48 | +0.33 | +0.62 | +1.15 |       |
| " . . . . .  | 13 x. 73    | 0   | 22       | -4    | 59    | -0     | 34     | +3                  | 17    | "      | 0      | 5      | +0.07  | -0.059  | -0.010                                    | -0.025                    | 32  | '836                        | 1.317          | -0.064  | -298  | -2                               | 11    | +1.21 | +0.48 | +0.33 | +0.62 | +1.15 |
| " . . . . .  | 15 x. 73    | -0  | 12       | -7    | 51    | -1     | 27     | -0                  | 5     | -0.05  | -0.03  | -0.02  | -0.01  | 32  | '836                                      | 1.317                     | -0.064  | -298                        | -2             | 11  | +1.21   | +0.48                            | +0.33 | +0.62 | +1.15 |       |       |       |
| " . . . . .  | x. 74       | -1  | 16       | -6    | 53    | -1     | 33     | +2                  | 41    | -0     | 18     | -0.025 | -0.047 | +0.017  | -0.028                                    | 32                        | '836  | 1.317                       | -0.064         | -298  | -2  | 11                               | +1.21 | +0.48 | +0.33 | +0.62 | +1.15 |       |
| " . . . . .  | x. 75       | -1  | 16       | -6    | 53    | -1     | 33     | +2                  | 41    | -0     | 18     | -0.025 | -0.047 | +0.017  | -0.028                                    | 32                        | '836  | 1.317                       | -0.064         | -298  | -2  | 11                               | +1.21 | +0.48 | +0.33 | +0.62 | +1.15 |       |
| " . . . . .  | x. 76       | -2  | 12       | -6    | 33    | -0     | 42     | +2                  | 44    | -0     | 18     | -0.038 | -0.057 | +0.028  | -0.038                                    | 32                        | '836  | 1.317                       | -0.064         | -298  | -2  | 11                               | +1.21 | +0.48 | +0.33 | +0.62 | +1.15 |       |

TABLE III.—Coefficients (continued).

\* Compass re-corrected on this day.

TABLE III.—Coefficients (continued).

| Place.                                       | Date.  | Approximate coefficients. |                           |          |           |          |           | Exact coefficients. |           |            |             |            |             | Coefficients of horizontal induction. | Part of $\frac{B}{A}$ from | Heeling coefficient for vertical force. |  |  |  |
|--|--|---------------------------|---------------------------|----------|-----------|----------|-----------|---------------------|-----------|------------|-------------|------------|-------------|---------------------------------------|----------------------------|---|--|--|--|
|  |  | A.                        |                           |          | B.        |          |           | C.                  |           |            | D.          |            |             |                                       |                            |   |  |  |  |
|  |  | $\alpha$                  | $\beta$                   | $\gamma$ | $\alpha'$ | $\beta'$ | $\gamma'$ | $\alpha''$          | $\beta''$ | $\gamma''$ | $\alpha'''$ | $\beta'''$ | $\gamma'''$ |                                       |                            |   |  |  |  |
| Spithead                                     | 8 iii. 67  | + 0 6                     | - 3 48                    | + 17 50  | + 3 3     | + 0 29   | + 0 29    | + 0 004             | - 0 067   | + 0 298    | + 0 053     | + 0 008    | - 0 016     | 12 57                                 | + 3 5                      | + 0 002                                 |  |  |  |
| "  | 15 iii. 67   | + 1 20                    | - 2 6                     | + 3 2    | + 2 25    | + 0 35   | + 0 023   | - 0 037             | + 0 032   | + 0 017    | + 0 010     | - 0 030    | + 0 061     | 1 12                                  | + 3 0                      | - 0 002                                 |  |  |  |
| Plymouth                                     | 2 viii. 72   | + 1 13                    | - 2 52                    | + 2 52   | + 3 0     | + 0 14   | + 0 016   | - 0 049             | + 0 042   | + 0 016    | + 0 010     | - 0 053    | + 0 004     | 2 52                                  | + 3 0                      | - 0 002                                 |  |  |  |
| Simon's Bay                                  | viii. 72   | - 0 50                    | - 2 31                    | - 2 53   | + 2 57    | - 0 18   | - 0 014   | - 0 046             | - 0 049   | - 0 016    | - 0 010     | - 0 052    | + 0 004     | 0 51                                  | - 0 005                    | - 0 002                                 |  |  |  |
| Plymouth                                     | 9 xi. 74   | + 0 25                    | - 2 42                    | + 2 42   | + 2 49    | + 0 9    | + 0 007   | - 0 018             | - 0 046   | + 0 049    | + 0 003     | - 0 047    | + 0 001     | 2 49                                  | + 2 42                     | - 0 002                                 |  |  |  |
| Simon's Bay                                  | 18 i. 75   | - 0 56                    | - 1 37                    | - 4 56   | + 2 58    | + 0 2    | - 0 016   | - 0 016             | - 0 030   | - 0 035    | + 0 052     | - 0 001    | - 0 001     | 5 21                                  | - 0 91                     | - 0 001                                 |  |  |  |
| Plymouth                                     | 18 vi. 75  | + 0 36                    | - 0 51                    | - 4 0    | + 2 46    | + 0 12   | + 0 010   | - 0 016             | - 0 039   | + 0 048    | - 0 004     | - 0 004    | - 0 004     | 4 2                                   | - 0 71                     | - 0 001                                 |  |  |  |
| Birkenhead                                   | 26 i. 76   | - 0 13                    | - 0 54                    | - 12 57  | + 3 5     | + 0 004  | - 0 004   | - 0 016             | - 0 028   | + 0 054    | + 0 002     | 13         | - 0 219     | 2 66                                  |                            |   |  |  |  |
| Spithead                                     | 2 iii. 76  | + 1 1                     | + 1 41                    | + 1 41   | + 1 12    | + 3 0    | + 0 18    | + 0 017             | + 0 030   | + 0 030    | + 0 005     | 2          | - 0 040     | 3 34                                  |                            |   |  |  |  |
| "  | 5 ix. 79   | - 3 21                    | - 5 40                    | + 2 4    | + 3 34    | + 0 12   | - 0 058   | - 0 013             | + 0 03    | + 0 037    | + 0 001     | 5 3        | - 0 092     | 1 119                                 |                            |   |  |  |  |
| Simon's Bay                                  | x. 79  | - 0 50                    | - 2 31                    | - 2 53   | + 2 57    | - 0 18   | - 0 014   | - 0 046             | - 0 049   | - 0 016    | - 0 005     | 3 1        | - 0 077     | 2 53                                  |                            |   |  |  |  |
| Mauritius                                    | .  | - 0 56                    | - 1 37                    | - 4 56   | + 2 58    | + 0 2    | - 0 016   | - 0 016             | - 0 030   | - 0 035    | + 0 052     | - 0 001    | - 0 001     | 5 21                                  | - 0 91                     | - 0 001                                 |  |  |  |
| Oreontes                                     | Iron screw; 5920 tons; 2570 H.P.; built at Birkenhead; head N. 68° W.; launched, 22 xi. 62.—Standard Compass.  |                           |                           |          |           |          |           |                     |           |            |             |            |             |                                       |                            |   |  |  |  |
| Himalaya                                     | Iron screw; 4690 tons; 2500 H.P.; built at Blackwall.—Standard Compass.  |                           |                           |          |           |          |           |                     |           |            |             |            |             |                                       |                            |   |  |  |  |
| <i>Iron trooships (continued).</i>           |  |                           |                           |          |           |          |           |                     |           |            |             |            |             |                                       |                            |   |  |  |  |
| Coura  | Iron and steel screw corvette, cased with wood; 2380 tons; 2450 H.P.; 14 guns. Built, Glasgow; head S. 11° W.; launched, 3 iv. 78.—Standard Compass.   |                           |                           |          |           |          |           |                     |           |            |             |            |             |                                       |                            |   |  |  |  |
| Carysfort                                    | Iron and steel screw corvette, cased with wood; 2380 tons; 2400 H.P.; 14 guns. Built, Glasgow; head S. 11° W.; launched, 26 ix. 78.—Standard Compass.  |                           |                           |          |           |          |           |                     |           |            |             |            |             |                                       |                            |   |  |  |  |
| Sheerness                                    | 5 xi. 79   | ...                       | From N.W. quadrant.       | 6 9      | ...       | ...      | ...       | - 0 011             | - 0 011   | + 0 098    | - 0 011     | ...        | ...         | 20 3                                  | 354                        | 937                                     |  |  |  |
| "  | 15 xi. 79  | + 0 50                    | From southern semicircle. | 6 9      | + 0 34    | ...      | ...       | + 0 014             | + 0 014   | - 0 017    | + 0 017     | ...        | 0 014       | 9 4                                   | 9 32                       | 1 073                                   |  |  |  |
| "  | 18 xii. 79   | ...                       | From north semicircle.    | 6 9      | ...       | ...      | ...       | + 0 032             | + 0 032   | - 0 010    | + 0 010     | ...        | 20 1        | 348                                   | 5                          |   |  |  |  |
| "  | 19 xii. 79   | +                         | 0 17                      | + 5 25   | + 0 52    | + 0 15   | + 0 005   | + 0 069             | + 0 069   | + 0 014    | + 0 014     | ...        | 5 1         | - 0 005                               | 6 155                      |   |  |  |  |
| Simon's Bay                                  | 20 iii. 80   | + 0 25                    | - 6 17                    | - 2 38   | - 5 02    | - 0 19   | - 0 006   | - 0 007             | - 0 007   | + 0 044    | + 0 044     | + 0 010    | + 0 010     | 6 106                                 | 8                          |   |  |  |  |
| Hong-Kong                                    | 12 viii. 80  | + 0 7                     | + 2 1                     | + 6 6    | + 6 8     | + 0 37   | + 0 002   | + 0 001             | + 0 018   | + 0 018    | + 0 018     | + 0 011    | + 0 011     | 1 018                                 | 87                         |   |  |  |  |
| Singapore                                    | 13 xii. 81   | - 0 17                    | - 0 1                     | + 1 18   | + 5 40    | + 0 42   | - 0 005   | - 0 001             | + 0 019   | + 0 019    | + 0 019     | + 0 012    | + 0 012     | 1 019                                 | 90                         |   |  |  |  |
| Cleopatra                                    | Steel and iron screw corvette, cased with wood; 2380 tons; 2610 H.P.; 14 guns. Built, Glasgow; head S. 11° W.; launched, 1 viii. 78.—Standard Compass. |                           |                           |          |           |          |           |                     |           |            |             |            |             |                                       |                            |   |  |  |  |
| Devonport                                    | 15 ix. 80  | ...                       | From southern semicircle. | 2 5      | + 6 16    | 0 35     | + 0 007   | + 0 054             | + 0 054   | + 0 066    | + 0 034     | + 0 009    | + 0 009     | 21                                    | 387                        | 358                                     |  |  |  |
| Monte Video                                  | 17 x. 80   | + 0 25                    | + 0 22                    | + 2 5    | + 6 16    | 0 35     | + 0 008   | + 0 057             | + 0 057   | + 0 057    | + 0 034     | + 0 010    | + 0 010     | I 3                                   | 37                         | 37                                      |  |  |  |
| Kobé, Japan                                  | 10 xi. 81  | - 0 50                    | - 1 52                    | + 1 48   | + 5 0     | - 0 18   | - 0 014   | - 0 038             | - 0 038   | - 0 029    | - 0 029     | - 0 002    | - 0 002     | II                                    | 200                        | 172                                     |  |  |  |
| Hong-Kong                                    | 20 xii. 81   | - 0 26                    | - 4                       | - 1 17   | + 6 16    | 0 34     | - 0 007   | - 0 074             | - 0 074   | - 0 074    | - 0 021     | + 0 012    | + 0 012     | I 3                                   | 173                        | 173                                     |  |  |  |
| <i>Iron and steel ships cased with wood.</i> |  |                           |                           |          |           |          |           |                     |           |            |             |            |             |                                       |                            |   |  |  |  |
| <i>Iron and steel ships cased with wood.</i> |  |                           |                           |          |           |          |           |                     |           |            |             |            |             |                                       |                            |   |  |  |  |
| Sheerness                                    |  |                           |                           |          |           |          |           |                     |           |            |             |            |             |                                       |                            |   |  |  |  |
| Simon's Bay                                  |  |                           |                           |          |           |          |           |                     |           |            |             |            |             |                                       |                            |   |  |  |  |
| Kobé, Japan                                  |  |                           |                           |          |           |          |           |                     |           |            |             |            |             |                                       |                            |   |  |  |  |
| Hong-Kong                                    |  |                           |                           |          |           |          |           |                     |           |            |             |            |             |                                       |                            |   |  |  |  |

\* Compass re-corrected on this day.

TABLE III.—Coefficients (continued).

| Place.   | Date.      | Approximate coefficients.                           |        |                      |  |             |       | Exact coefficients.                        |       |              |        |                  |                  | Coefficients of horizontal induction. |                      | Part of $\frac{g}{\tan \theta}$ from |  | Heeling coefficient for Variable part of vertical force. |                           |  |
|--|------------|---|--------|----------------------|--|-------------|-------|--|-------|--------------|--------|------------------|------------------|---------------------------------------|----------------------|--------------------------------------|--|--|---------------------------|--|
|  |            | From semi-circular deviation.<br>$\sqrt{B^2 + C^2}$ |        |                      | Mean horizontal force of ship.<br>$\sqrt{B^2 + C^2}$ |             |       | Mean force to north.<br>$\sqrt{B^2 + C^2}$ |       |              | I.     |                  | Head-ward.<br>a. |                                       | To star-board.<br>e. |                                      | Vertical force and induction in transverse iron. |  | $\frac{g}{\tan \theta}$ . |  |
|  |            | A.  | B.     | C.                   | D.   | E.          | F.    | G.   | H.    | I.           | J.     | K.               | L.               | M.                                    | N.                   | O.                                   | P.   | g.   |                           |  |
| <i>Composite vessels.</i>  |            |   |        |                      |  |             |       |  |       |              |        |                  |                  |                                       |                      |                                      |  |  |                           |  |
| RUBY.—Composite screw corvette; 2120 tons; 1820 H.P.; 12 guns. Built, Hull; head N. $3^\circ$ W.; launched, 10 viii. 76.—Standard Compass.                             |            |   |        |                      |  |             |       |  |       |              |        |                  |                  |                                       |                      |                                      |  |  |                           |  |
| Sheerness . . . . .  | 30 vi. 77  | -0.56   | -1.19  | -0.45                | +5.48  | ...<br>0.53 | -0.16 | -0.04                                      | +10.1 | ...<br>-0.11 | -0.128 | +10.1            | ...<br>-0.15     | 25 $\frac{1}{3}$                      | 140                  | 197                                  |  |  |                           |  |
| " . . . . .  | 3 viii. 77 | -0.56   | -1.19  | -0.45                | +5.48  | ...<br>0.53 | -0.16 | -0.04                                      | +10.1 | ...<br>-0.11 | -0.128 | +10.1            | ...<br>-0.15     | 14 $\frac{1}{3}$                      | .026                 | .205                                 |  |  |                           |  |
| Gulf of Xeros . . . . .  | iii. 78    | -0.44   | -1.18  | +0.7                 | +6   | 9 -0.6      | -0.13 | -0.04                                      | +10.7 | ...<br>+0.02 | -0.123 | -0.02            | 1 $\frac{1}{4}$  | .024                                  | .176                 |                                      |  |  |                           |  |
| Singapore . . . . .  | vii. 78    | +0.45   | -2.69  | +0.38                | +0.15  | +0.13       | -0.05 | +0.01                                      | +10.7 | ...<br>+0.02 | -0.123 | -0.02            | 2 $\frac{1}{4}$  | .036                                  | .170                 |                                      |  |  |                           |  |
| Rangoon . . . . .  | x. 78      | -0.33   | -2.92  | -0.58                | +5   | 0.6         | -0.04 | -0.06                                      | +10.6 | ...<br>+0.02 | -0.123 | -0.02            | 2 $\frac{1}{4}$  | .049                                  | .199                 |                                      |  |  |                           |  |
| Zanzibar . . . . .   | 12 iii. 80 | +0.26   | -4.20  | +4.0                 | 5  | +0.03       | -0.79 | -0.07                                      | +10.7 | ...<br>+0.02 | -0.123 | -0.02            | 4 $\frac{1}{4}$  | .079                                  | .185                 |                                      |  |  |                           |  |
| <i>GANNER.—Composite screw sloop; 1130 tons; 1110 H.P.; 6 guns. Built, Sheerness; head S. <math>76^\circ</math> E.; launched, 31 viii. 78.—Standard Compass.</i>       |            |   |        |                      |  |             |       |  |       |              |        |                  |                  |                                       |                      |                                      |  |  |                           |  |
| Sheerness . . . . .  | 29 iv. 79  | -0.52   | +11.20 | +9.17                | -1.1   | 22 + 0.11   | -0.15 | +20.1                                      | +15.5 | +0.09        | +0.03  | 14 $\frac{1}{3}$ | .233             | .38                                   | .895                 | 1.117                                | .864   | + 0.41   |                           |  |
| " . . . . .  | 30 iv. 79  | -0.43   | +2.54  | +0.42                | +3.47  | 0.7         | -0.12 | +0.02                                      | +0.12 | +0.06        | +0.02  | 3                | .053             | .13                                   | .895                 | 1.117                                | .864   | + 0.41   |                           |  |
| Conquimbo . . . . .  | x. 79      | +0.25   | -3.15  | -1.24                | +3.55  | +0.36       | +0.07 | -0.05                                      | -0.02 | +0.08        | +0.02  | 3 $\frac{1}{4}$  | .033             | .09                                   | .033                 | 1.117                                | .864   | + 0.41   |                           |  |
| Esquimaule . . . . .   | vii. 81    | -0.2  | +1.17  | -0.53                | +3.26  | -0.21       | -0.01 | +0.04                                      | +0.02 | -0.05        | +0.02  | 4 $\frac{1}{4}$  | .028             | .028                                  | .028                 | 1.117                                | .864   | + 0.41   |                           |  |
| <i>ALBATROSS.—Composite screw sloop; 940 tons; 840 H.P.; 4 guns. Built, Chatham; head S. <math>50^\circ</math> E.; launched, 27 viii. 73.—Standard Compass.</i>        |            |   |        |                      |  |             |       |  |       |              |        |                  |                  |                                       |                      |                                      |  |  |                           |  |
| Sheerness . . . . .  | 29 xii. 73 | -0.38   | +16.33 | +6.17                | +3   | 59 -0.24    | -0.11 | +29.5                                      | +10.1 | +0.05        | +0.03  | 17 $\frac{1}{3}$ | .070             | -0.007                                | 17 $\frac{1}{3}$     | .017                                 | .20  | + 0.41   |                           |  |
| " . . . . .  | 20 xii. 74 | -1.31   | +0.19  | +0.52                | +4   | 1 -0.06     | -0.05 | +0.05                                      | +0.06 | +0.03        | +0.02  | 1                | .017             | .017                                  | .017                 | .017                                 | .017   | + 0.41   |                           |  |
| Rio de Janeiro . . . . .   | 5 vii. 74  | -0.39   | -2.65  | +0.45                | +4   | 14 + 0.6    | -0.11 | -0.05                                      | -0.12 | +0.03        | +0.02  | 3                | .054             | .193                                  | .054                 | .054                                 | .054   | + 0.41   |                           |  |
| Plymouth . . . . .   | 10 x. 74   | +0.10   | +0.10  | +0.24                | +0.24  | 3 -0.06     | -0.02 | +0.02                                      | +0.03 | +0.03        | +0.02  | 4 $\frac{1}{4}$  | .024             | .024                                  | .024                 | .024                                 | .024   | + 0.41   |                           |  |
| Taboga . . . . .   | 27 x. 75   | -0.20   | -1.44  | -0.12                | +3.44  | +0.9        | -0.06 | +0.03                                      | +0.03 | +0.06        | +0.03  | 1 $\frac{1}{4}$  | .031             | .186                                  | .031                 | .031                                 | .031   | + 0.41   |                           |  |
| Pisco . . . . .  | 15 xii. 76 | +0.31   | -2.58  | +0.41                | +0.06  | +0.28       | -0.05 | +0.01                                      | +0.01 | +0.01        | +0.01  | 3 $\frac{1}{4}$  | .051             | .179                                  | .051                 | .051                                 | .051   | + 0.41   |                           |  |
| Esquimaule . . . . .   | 29 x. 77   | -0.47   | +0.16  | +0.56                | +3.26  | -0.6        | -0.14 | +0.05                                      | +0.06 | +0.01        | +0.01  | 4 $\frac{1}{4}$  | .017             | .028                                  | .017                 | .017                                 | .017   | + 0.41   |                           |  |
| <i>BOXER.—Composite double screw gun vessel; 603 tons; 590 H.P.; 4 guns. Built, Deptford; head S. <math>60^\circ</math> W.; launched, 25 vi. 68.—Standard Compass.</i> |            |   |        |                      |  |             |       |  |       |              |        |                  |                  |                                       |                      |                                      |  |  |                           |  |
| Greenhithe . . . . .   | 30 xi. 68  | -0.11   | +1.31  | -1.27                | +3.39  | 0.20        | +0.03 | +1.95                                      | -1.61 | +0.07        | +0.02  | 14 $\frac{1}{3}$ | .253             | .220                                  |                      |                                      |  | + 0.34   |                           |  |
| Rio de Janeiro . . . . .   | 20 ii. 69  | +0.6  | -0.49  | -4.15                | -3.50  | -0.24       | +0.03 | +1.95                                      | -1.61 | +0.07        | +0.02  | 14 $\frac{1}{3}$ | .253             | .220                                  |                      |                                      |  | + 0.34   |                           |  |
| Esquimaule . . . . .   | 1 x. 69    | -0.8  | +3.42  | -2.63                | +2.33  | -0.02       | +0.03 | +1.95                                      | -1.61 | +0.07        | +0.02  | 14 $\frac{1}{3}$ | .253             | .220                                  |                      |                                      |  | + 0.34   |                           |  |
| Konax, Vancouver Island . . . . .  | 24 iv. 71  | +1.33   | +2.52  | -3.27                | +2.52  | -0.19       | +0.19 | +1.95                                      | -1.61 | +0.07        | +0.02  | 14 $\frac{1}{3}$ | .253             | .220                                  |                      |                                      |  | + 0.34   |                           |  |
| Esquimaule . . . . .   | 30 xii. 74 | -2.52   | +4.47  | -1.46                | +3.18  | +0.24       | +0.03 | +1.95                                      | -1.61 | +0.07        | +0.02  | 14 $\frac{1}{3}$ | .253             | .220                                  |                      |                                      |  | + 0.34   |                           |  |
| Coquimbo . . . . .   | 13 v. 75   | -1.05   | -0.59  | -0.5                 | +2.20  | -0.10       | +0.03 | +1.95                                      | -1.61 | +0.07        | +0.02  | 14 $\frac{1}{3}$ | .253             | .220                                  |                      |                                      |  | + 0.34   |                           |  |
| <i>PEER.—Composite double screw gun vessel; 603 tons; 590 H.P.; 4 guns. Built, Glasgow; head S. <math>65^\circ</math> W.; launched, 22 vi. 68.—Standard Compass.</i>   |            |   |        |                      |  |             |       |  |       |              |        |                  |                  |                                       |                      |                                      |  |  |                           |  |
| Devonport . . . . .  | 3 ii. 70   | +1  | "      | From N.E. gun adavit | +0.30  | +0.31       | +0.17 | +251                                       | -186  | +0.65        | +0.09  | 18               | .312             | .323                                  |                      |                                      |  | + 0.45   |                           |  |
| Elephant Bay, W. Coast of Africa . . . . .   | 8 ii. 70   | +1  | "      | From N.E. gun adavit | +0.46  | +0.47       | +0.13 | +251                                       | -186  | +0.65        | +0.09  | 14 $\frac{1}{4}$ | .021             | .307                                  | .939                 | 1.065                                | + 0.45   | + 0.45   |                           |  |
| Rio de Janeiro . . . . .   | 29 xii. 71 | -0  | 7      | -3.30                | -2.15  | +2.59       | -1.35 | +0.55                                      | -0.62 | +0.52        | -0.38  | 4 $\frac{1}{4}$  | .073             | .202                                  |                      |                                      |  | + 0.45   |                           |  |

TABLE III.—Coefficients (continued).

| Place.   | Date.       | Approximate coefficients. |         |         |        |        |         | Exact coefficients. |         |         |         |         |         | Maximum of semi-circular deviation.<br>$\sqrt{B^2 + C^2}$ | Mean horizontal force of ship.<br>$\sqrt{B^2 + C^2}$ | Mean horizontal force to north.<br>$\frac{1}{\lambda}$ | Coefficients of horizontal induction. | Part of $\bar{D}$ from<br>Head-<br>ward. | Fore<br>and<br>aft<br>induc-<br>tion. | Trans-<br>verse<br>induc-<br>tion. | Heeling<br>coeffi-<br>cient for<br>iron. | Variable part<br>of vertical<br>force.<br>$\frac{g}{\tan \theta} \cdot g$ . |
|--|-------------|---------------------------|---------|---------|--------|--------|---------|---------------------|---------|---------|---------|---------|---------|---|--|--|---------------------------------------|--|---------------------------------------|------------------------------------|--|---|
|  |             | A.                        | B.      | C.      | D.     | E.     | F.      | G.                  | H.      | I.      | J.      | K.      | L.      |   |  |  |                                       |  |                                       |                                    |  |   |
|  |             | o                         | /       | o       | /      | o      | /       | o                   | /       | o       | /       | o       | /       |   |  |  |                                       |  |                                       |                                    |  |   |
| Plymouth . . . .   | 24 vi. 79   | + 0 45                    | + 0 45  | + 0 35  | + 0 57 | + 3 45 | + 0 18  | + 0 13              | + 0 16  | + 0 16  | + 0 06  | + 0 05  | + 0 05  | 18  | + 330  | 180  |                                       |  |                                       |                                    |  |   |
| " False Bay, C. . .  | "           | + 0 45                    | + 0 45  | + 0 35  | + 0 57 | + 3 45 | + 0 18  | + 0 13              | + 0 16  | + 0 16  | + 0 06  | + 0 05  | + 0 05  | $I_{\frac{1}{4}}$   | -023   | 45   |                                       |  |                                       |                                    |  |   |
| Good Hope . . . .  | 29 vi. 80   | - 0 23                    | - 0 14  | + 0 14  | + 0 14 | + 0 14 | + 0 14  | + 0 14              | + 0 14  | + 0 14  | + 0 01  | + 0 01  | + 0 01  | $I_{\frac{1}{4}}$   | -023   | 45   |                                       |  |                                       |                                    |  |   |
| Gabon R. . . .   | 30 viii. 80 | + 0 32                    | + 1 32  | + 1 42  | + 3 40 | + 0 45 | + 0 09  | + 0 09              | + 0 09  | + 0 09  | + 0 04  | + 0 04  | + 0 04  | $I_{\frac{1}{4}}$   | -023   | 45   |                                       |  |                                       |                                    |  |   |
| <i>Composite vessels (continued).</i>  |             |                           |         |         |        |        |         |                     |         |         |         |         |         |   |  |  |                                       |  |                                       |                                    |  |   |
| <i>WREYLY.—Composite screw gunboat; 455 tons; 470 H.P.; 4 guns. Built, Glasgow; head N. 26° E.; launched, 28 vi. 77.—Standard Compass.</i>                                   |             |                           |         |         |        |        |         |                     |         |         |         |         |         |   |  |  |                                       |  |                                       |                                    |  |   |
| Plymouth . . . .   | 26 v. 81    | - 0 37                    | - 10 28 | + 20 28 | + 3 15 | - 0 30 | - 0 11  | - 0 183             | + 0 07  | + 0 09  | + 0 09  | + 0 09  | + 0 09  | 23  | + 385  | 117  |                                       |  |                                       |                                    |  |   |
| " Simon's Bay . . . .  | 31 xii. 81  | - 0 4                     | - 0 4   | + 0 45  | + 0 45 | + 0 15 | + 0 15  | + 0 12              | + 0 04  | + 0 04  | + 0 04  | + 0 04  | + 0 04  | $I_{\frac{1}{4}}$   | -013   | 162  |                                       |  |                                       |                                    |  |   |
| " " . . . .  | "           | - 0 52                    | - 1 52  | + 1 32  | + 5 2  | + 0 9  | + 0 9   | + 0 15              | + 0 20  | + 0 20  | + 0 08  | + 0 08  | + 0 08  | $I_{\frac{1}{4}}$   | -017   | 232  |                                       |  |                                       |                                    |  |   |
| Grenada . . . .  | 30 x. 76    | - 0 36                    | - 0 42  | - 0 37  | + 3 20 | - 0 22 | + 0 22  | + 0 09              | + 0 09  | + 0 09  | + 0 05  | + 0 05  | + 0 05  | $I_{\frac{1}{4}}$   | -016   | 218  |                                       |  |                                       |                                    |  |   |
| <i>Wooden ships with iron beams and vertical bulkheads.</i>  |             |                           |         |         |        |        |         |                     |         |         |         |         |         |   |  |  |                                       |  |                                       |                                    |  |   |
| <i>ENCOUNTER.—Wood corvette, iron beams and iron transverse bulkheads from keel to lower deck. Built at Sheerness; head S. 75° E.; launched, 6 xi. 69.—Standard Compass.</i> |             |                           |         |         |        |        |         |                     |         |         |         |         |         |   |  |  |                                       |  |                                       |                                    |  |   |
| Sheerness . . . .  | 2 ix. 73    | - 0 31                    | + 13 24 | + 9 27  | + 4 12 | + 0 20 | - 0 01  | + 0 01              | + 0 01  | + 0 01  | + 0 06  | + 0 06  | + 0 06  | 16 $\frac{1}{2}$  | + 287  | 33   |                                       |  |                                       |                                    |  |   |
| " Simon's Bay . . . .  | 9 ix. 73    | + 0 35                    | + 3 32  | + 2 8   | + 0 14 | - 0 11 | + 0 11  | + 0 06              | + 0 06  | + 0 06  | + 0 03  | + 0 03  | + 0 03  | $I_{\frac{1}{4}}$   | -074   | 29   |                                       |  |                                       |                                    |  |   |
| " " . . . .  | 11 iv. 74   | + 1 18                    | - 1 26  | + 1 19  | + 3 40 | + 1 0  | + 0 01  | + 0 020             | + 0 020 | + 0 020 | + 0 04  | + 0 04  | + 0 04  | $I_{\frac{1}{4}}$   | -034   | 140  |                                       |  |                                       |                                    |  |   |
| " " . . . .  | 15 x. 74    | + 0 36                    | - 1 10  | + 0 27  | + 4 43 | + 0 28 | + 0 01  | + 0 021             | + 0 021 | + 0 021 | + 0 08  | + 0 08  | + 0 08  | $I_{\frac{1}{4}}$   | -022   | 160  |                                       |  |                                       |                                    |  |   |
| Grenada . . . .  | 20 i. 76    | - 1 9                     | - 4 12  | - 0 12  | + 2 38 | - 0 53 | + 0 53  | + 0 020             | + 0 020 | + 0 020 | + 0 05  | + 0 05  | + 0 05  | $I_{\frac{1}{4}}$   | -076   | 185  |                                       |  |                                       |                                    |  |   |
| <i>SAPPHIRE.—Wood corvette, iron beams and iron transverse bulkheads from keel to lower deck. Built at Devonport; head E.; launched, 24 ix. 74.—Standard Compass.</i>        |             |                           |         |         |        |        |         |                     |         |         |         |         |         |   |  |  |                                       |  |                                       |                                    |  |   |
| Devonport . . . .  | 21 viii. 75 | - 0 22                    | + 18 44 | + 7 24  | + 4 7  | - 0 23 | + 0 06  | + 0 06              | + 0 06  | + 0 06  | + 0 03  | + 0 03  | + 0 03  | 20  | + 352  | 20   |                                       |  |                                       |                                    |  |   |
| " Wellington, N.Z. . .   | 24 viii. 75 | - 0 17                    | + 1 3   | + 0 45  | + 4 9  | - 0 17 | + 0 06  | + 0 06              | + 0 06  | + 0 06  | + 0 03  | + 0 03  | + 0 03  | $I_{\frac{1}{4}}$   | -022   | 36   |                                       |  |                                       |                                    |  |   |
| " Sydney, N.S.W. . .   | 30 xi. 75   | - 0 5                     | - 8 54  | + 0 49  | + 3 35 | + 0 20 | + 0 01  | + 0 01              | + 0 01  | + 0 01  | + 0 06  | + 0 06  | + 0 06  | $I_{\frac{1}{4}}$   | -060   | 175  |                                       |  |                                       |                                    |  |   |
| " " . . . .  | xii. 75     | - 0 49                    | - 10 43 | + 0 5   | + 3 0  | - 0 52 | - 0 014 | - 0 014             | - 0 014 | - 0 014 | - 0 017 | - 0 017 | - 0 017 | $I_{\frac{1}{4}}$   | -089   | 179  |                                       |  |                                       |                                    |  |   |
| " " . . . .  | viii. 77    | - 0 10                    | - 11 20 | - 1 25  | + 3 48 | + 0 15 | - 0 003 | - 0 003             | - 0 003 | - 0 003 | - 0 024 | - 0 024 | - 0 024 | $I_{\frac{1}{4}}$   | -004   | 187  |                                       |  |                                       |                                    |  |   |